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NOTES
ON
MILITARY SURVEYING
AND
RECONNAISSANCE

LIEUT.-COLONEL PATERSON

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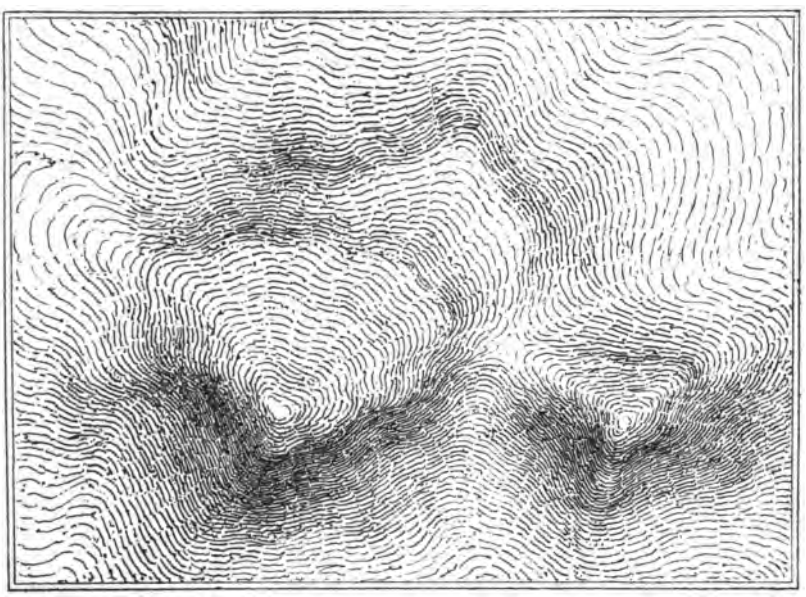
Specimen

of

MILITARY DRAWING.



Etched on copper by the late Major R. Petley.

1862.

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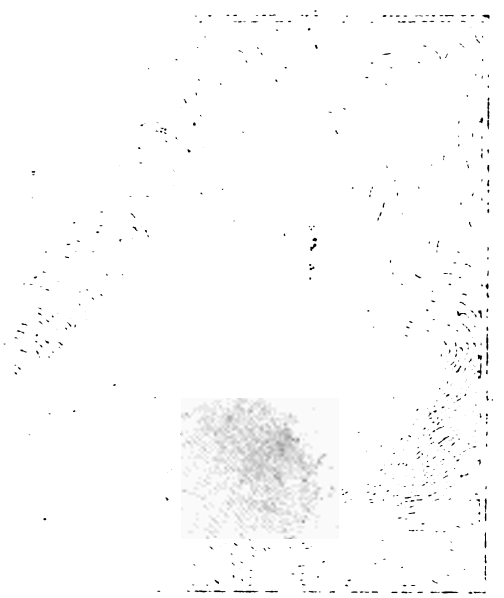

Major R Pelley

NOTES

ON

Military Surveying & Reconnaissance.

BY

LIEUT.-COLONEL WILLIAM PATERSON,

PROFESSOR OF MILITARY SURVEYING AT THE ROYAL MILITARY COLLEGE, SANDHURST.

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PREFACE.

THE adoption in the British Army of a certain uniform scale of shade for the representation of slopes, together with the compulsory introduction of contours on all future military plans,* has necessitated the preparation of these Supplementary Notes to my already published Treatise on Military Drawing and Surveying. It is to be hoped, however, that the directions as to always showing the contours may soon be modified; as the system, although possibly applicable to elementary instruction, would be found impracticable in actual warfare.

These Notes are intended as a guide to Officers in preparing for their examinations in Topography, and from the success of the five previous editions it is gratifying to conclude that they have entirely answered the purpose for which they were intended.

It has lately been considered requisite that all Officers should be capable of making Topographical Reports in addition to having a knowledge of Field-Sketching. The

* "Memorandum on Topography for the Military Colleges." Approved by His Royal Highness the Field-Marshal Commanding in Chief. Signed, Wm. Napier, Major-General, Vice-President, Council of Military Education. 23d February 1867.

present edition has consequently been unavoidably still further extended, and has been made to embrace not only the most useful parts of Reconnaissance, but also the latest innovations in Topography submitted to the War Office Sub-Committee, of which I have the honour of being a Member. It will now be found to contain all the information that is laid down as at present necessary in the Syllabus for the Army Examinations in this branch.

The Frontispiece is from the hand of the late Major Petley, my friend, colleague, and immediate predecessor, the best military draughtsman whom we have ever yet had; and to whom the British Army is indebted for the great stride in advance which it has taken in this subject of late years.

THE TERRACE,
ROYAL MILITARY COLLEGE,
March 1882.

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FRONTISPIECE.

Specimen of Military Drawing.

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MILITARY DRAWING

AND

SURVEYING.

GENERAL PRINCIPLES OF READING MAPS.

1.—Definitions of Military Topography.

Military Topography comprises the consideration of the artificial as well as the natural objects of a country with reference to their influence on military operations. Mountain ranges and rivers are the most important natural points, whilst, amongst the artificial features, roads and fortifications are those which have the greatest influence. The subject may be divided into the two headings of Military Surveying and Military Drawing.

Military Surveying may be defined as the art of representing ground in such a manner that an officer may be able, by means of a scale, to measure the horizontal dimensions, and also, from the formation of the features as well as the depth of shade, to form such a judgment as will enable him to decide on their applicability to the different purposes of war.

Military Drawing is the method of expressing upon paper, according to certain conventional rules, the various objects which the face of a country presents, and which are required to be delineated by the topographical draughtsman.

As a preliminary to a just appreciation of the subject of drawing maps, it is well, if possible, to begin by comparing military drawings with the models of the ground they represent, and then to proceed to extensive maps and to compare them with

the actual country in the field. By this plan the student will be familiarised with the relative positions and distances in which the objects stand to one another, and the conventional representations of the configuration of the different kinds of features of ground; together with that of roads, rivers, woods, houses, cultivation, and other technical details.

To compare a drawing with the model from which it was taken is, relatively, an easy process; as the eye being almost directly above both of them, the shapes and positions of the different objects can at once be recognised; but there is greater difficulty when the observer first attempts to search out his position on a map, from the appearance of the objects themselves in the country.

(PLATE XV.*) To understand any map, the two first principles are to look to the lie and direction of the streams, by noticing how the smaller water-courses, A, B, C, are generally found to tend, as at D, E, F, towards the direction of the current of the main channel GH, which in its turn will perhaps flow to some large lake or sea, showing the lowest level; and secondly, to discover where the features of ground project, as at J, K, L, M. towards the streams. These latter will show the positions of the water-sheds, when, consequently, the recesses will represent the valleys, and the relative commands of the different hills can be ascertained. Contours may, perhaps, help to elucidate both these points.

The first thing that is necessary on taking a map into the field is to find the means of spreading it out in a position corresponding with the objects in nature. This is done by making the north points coincide; but as the true north of a map is generally the top, or at all events marked on it on some conspicuous place, and the observed north in the country taken with a compass † are not the same, an allowance has to be made for the magnetic variation of the needle.‡

The simplest plan is, in England, to subtract (but adding where necessary in other countries) the variation from all observed angles, so as to reduce them at once to true north on the map, before discovering from it the relative required positions of the objects.

* Each diagram has a number near it, corresponding with the section to which it refers. † See section 36. ‡ See section 34.

Direct observation with an instrument from any given place will, with the aid of a protractor adjusted approximately north and south,* enable any visible object to be recognised; but to find the unknown position of an observer on the map, and from it his position in the country, the method of interpolation has to be resorted to.†

A ready acquaintance with the conventional expression of the different objects by certain signs‡ is, of course, of vital consequence in reading maps, as well as the power of appreciating and measuring off scales of distances.§ The most crucial test that the subject has been thoroughly understood is the power of making sections of ground ‖ through any required lines of country. In fact, the student must from the very first, unconsciously to himself, have been running imaginary sections; and where, as at an examination, he may be asked precise questions on reading ground, his only safe and reliable method of answering will be by the actual construction of one or more sections over the line indicated.

2.—Different Theories of Expressing Ground.

The reading of ground is attained by studying and forming a just appreciation of the relative heights of hills, as generally shown by contours; the steepness of the slopes, as shown by the depth of shade; and the formation of the features, as expressed by the character of drawing.

There are three principal and distinct methods of expressing hills upon paper.

(Plate XIII.) The first method is to suppose a sheet of light in parallel rays to fall upon ground from directly above it. Wherever the ground is level, the appearance will be white; when it slopes, the rays falling obliquely on the surface will give a dark appearance; and as it becomes more precipitous, it will of course be still darker. This is the theory of the style of drawing which is done with a brush, and successive shades of Indian ink or other tint. An attempt is now being made to carry out this system more expeditiously with shades of pow-

* See section 32. † See section 44.
‡ See sections 27 to 30. § See section 7. ‖ See sections 17 to 22.

dered blacklead applied with a leather stump, as will be found afterwards explained in Section 119.

(PLATE XII.) In the second method, a volume of water is supposed to fall on a hill. Wherever the slopes are gentle, the water will run off in small thin rills, diverging as they descend; in the abrupt slopes, it will rush down in large broad streams. This is the theory of the vertical system; only, to avoid stiffness, the lines are broken into a series of successive strokes, not following one another down the hills.

(PLATE XI.) In the third method, the hills may be imagined as inundated with water, and that every time the water falls a certain fixed number of feet, a mark is run round the surface of the ground at the upper edge of the water. According to the steepness of the falls, the lines, to an eye placed immediately above them, will appear close or far apart. This is called the contour or horizontal system, and is applied in field-sketching; the strokes being broken instead of being carried continuously round; and the effect of the shading increased by making them thicker, as well as closer on the steeper slopes, and lighter, longer, and wider apart on the more gentle declivities.

3.—SCALE OF SLOPES FOR EACH ARM OF THE SERVICE.

(PLATE II.) The following is the scale of slope which has been laid down by the "Aide-Mémoire to the Military Sciences," for the operations of each arm of the service. They are according to the scale generally adopted, but they are infinitely too steep in practice for the movement of troops.

60°	or $\frac{7}{4}$	Inaccessible for infantry.
45°	„ $\frac{1}{1}$	Difficult for infantry.
30°	„ $\frac{4}{7}$	Inaccessible for cavalry.
15°	„ $\frac{1}{4}$	Inaccessible for artillery.
5°	„ $\frac{1}{12}$	Accessible for carriages.

It has been constructed on the supposition that the troops ascend directly up these slopes and in military order. It would, consequently, not apply in the case of skirmishers, nor where the ground being loose, or even rocky, men are permitted to ascend diagonally with unlimited time at their disposal. The relative slopes may be seen in the diagram.

Of course the nature of the soil and the character of the roads will materially vary this scale.

It may be presumed that any slope immediately under those marked as inaccessible, may be taken as very difficult. 15° is considered the limit of manœuvring ground, although instances are on record of troops scaling almost precipitous heights.

DRAWING FROM PLATES ON THE HORIZONTAL SYSTEM.

4.—On Copying Military Drawings.

The general method of copying military drawings is by a system of squares, which are first traced on the plate to be copied. It will be found convenient to lay off the equal distances from the upper left-hand corner of the boundary line, any unequal spaces consequently falling to the right and bottom of the drawing.

In copying the squares on to the drawing paper, the boundary line must first be laid down, and equal distances corresponding with the squares on the plate marked upon it: these points being joined will complete the squares. Should it be required to make the copy of an increased or diminished size to that of the original drawing, all that is necessary is to make the squares on the drawing paper larger or smaller, in the same relative proportion to those on the original.

The outline of the drawing is copied by observing where the different objects cross the copying squares, and by tracing them in pencil in their corresponding positions on the drawing paper. The drawing is afterwards finished as directed in the next section.

The squares may be rubbed out as the work proceeds, but they must at all events be obliterated when it is finished.

Drawings are sometimes copied, where it is an object not to injure the originals, either directly through a sheet of glass, when neither the paper of the original nor the copy are too thick, or by tracing them through a thin transparent paper prepared for the purpose. This tracing paper bearing the outline is laid on

the drawing paper, with a sheet of paper blackened on one side inserted face downwards between them; a pencil is then run over the lines already traced.

(PLATE XV.) An instrument called a Pantagraph is an even more expeditious way of copying as well as for enlarging and reducing maps. A substitute for one of an expensive kind may be made in the following manner.

Take four slips of wood, about 13 inches long, half an inch broad, and one-eighth of an inch in thickness. Bore a small hole half an inch from each end of each slip of wood, which will leave 12 inches between the holes. From the hole at one end of each, mark off points at 1, 1½, 2, 3, 4, and 6 inches. Figure them as in the diagram, noticing that the two left-hand ones are marked downwards and the other two upwards.

Improvise, as a fulcrum at B, a heavy weight such as any flat piece of metal, with a wire pivot projecting vertically from it. Provide four thin convex-headed screws; fix three of them head downwards at A, D, and E; file one to a point and screw it in at F. Insert a pencil point downwards at C. These points must all rest on the same plane. When constructed, the instrument will consist of four arms, AB, AC, DF, EF, capable of turning freely on axes A, D, E, F; and always so adjusted by the graduated arms as to form a parallelogram between these points, with the power of increasing or diminishing a map to six different scales varying from two to twelve times the original.

The end B is placed on the table as a fulcrum, F carries a tracer for going over the original drawing, and C a pencil for making the copy. When these three are in a straight line the instrument is correctly set; and, from the construction of it, this rectilinear direction of the points is retained whatever be its position about the fulcrum.

It is evident that wherever the axis D is set on AB (in the diagram it is put for an increase of four times) establishes the ratio between the distance of BD and BA to that between BF and BC; hence, if the tracing point at F be made to pass over the lines on any given map, a pencil at C will describe a similar but larger figure to corresponding lines in the given figure. If the tracing point and pencil were to be placed in inverted positions, a figure of diminished size would be obtained. If the

fulcrum was placed between the pointer and pencil, a copy of equal size, but in a reversed position, would be traced.

Should any difficulty be found in making the pencil show the outline on the paper, the pencil itself, instead of the tracer, may be held in the hand whilst the latter is going over the drawing.

By the parallel adjustment of the graduated arms to a combination of the distances marked on them, scales of $2\frac{1}{2}$, $3\frac{1}{2}$, $4\frac{1}{2}$, 5, $5\frac{1}{2}$, 7, $7\frac{1}{2}$, 9, and 10 can also be obtained; for, on fixing any two of the marked distances together, a scale of one-half of the sum of them is found. As an example $\frac{8+3}{2} = 5\frac{1}{2}$ scale.

5.—Order of Drawing Features of Ground.

The preliminary stage in copying horizontal drawings consists in sketching lightly the roads, rivers, edges of rocks, and sea-line or other impediment to the shading; proceeding then to put in the tops of the principal hills, and afterwards in succession the upper edges of the under-features * springing from them.

The outlines of the features of the ground will, in the case of a contoured plan, merely consist of the most important contours; * but in one which is not contoured, they will be composed of the crests* of the hills, and the upper edge of each change of slope. In the latter case they should be sketched in very lightly, and rubbed out as the work proceeds.

In the intermediate stage the successive contours are drawn under the original outlines, and permanently marked with some very light colour in chain-dotted or continuous lines.

The final stage comprises the completing of the shading, which should be commenced at one of the principal hills near the centre of the paper, worked from the higher ground downwards without actually stopping at a change of slope or a contour, as represented at E, F, and G in one of the diagrams to section 15 in Plate II., in order to avoid getting it into a succession of bands of shading, and the individual strokes should not, as far as possible, be made continuous.

* See Section 45, which contains an explanation of conventional terms or references to other sections where they can be obtained.

6.—Elementary Directions for Shading.

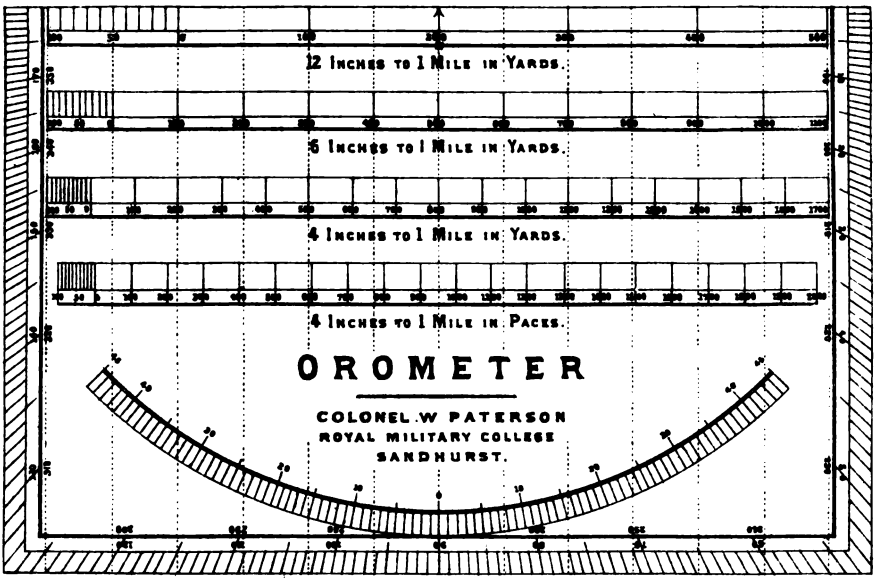
(Plate II.) There is a prospect of showing the slopes of ground by reverting to the plan of a kind of mezzotint, as will be found in Section 119, but in the meantime the horizontal system is the one generally adopted for field-sketching, and should at first be practised by copying from plates without reference to any restrictions as to scale of shade. After freedom and facility have been acquired, drawing by scale can be perfected in a few hours.

In all military drawings each individual line should be drawn with an even pressure throughout, directly towards the draughtsman, the paper being constantly turned to adapt itself to this position; the strokes in the aggregate should, however, be laid down alongside of the one previously drawn in the order as shown from A to B, and never as from A to C. To do this the hand should be accustomed to work freely from the right towards the left as from the left towards the right. The strokes should be short, of the same thickness throughout their length, and curved, to suit the general gradations and direction of true contours. Neither the upper nor the lower slopes of hills should be harshly begun or ended, but where necessary they should be gradually softened off by delicate shading into the surrounding level ground. The shading of the upper-features* should be kept in advance of the lower ones, and brought down in each case from the main re-entrants* to the salients.* The actual steepness can alone be secured by carefully copying the thickness and distance apart of the individual strokes.

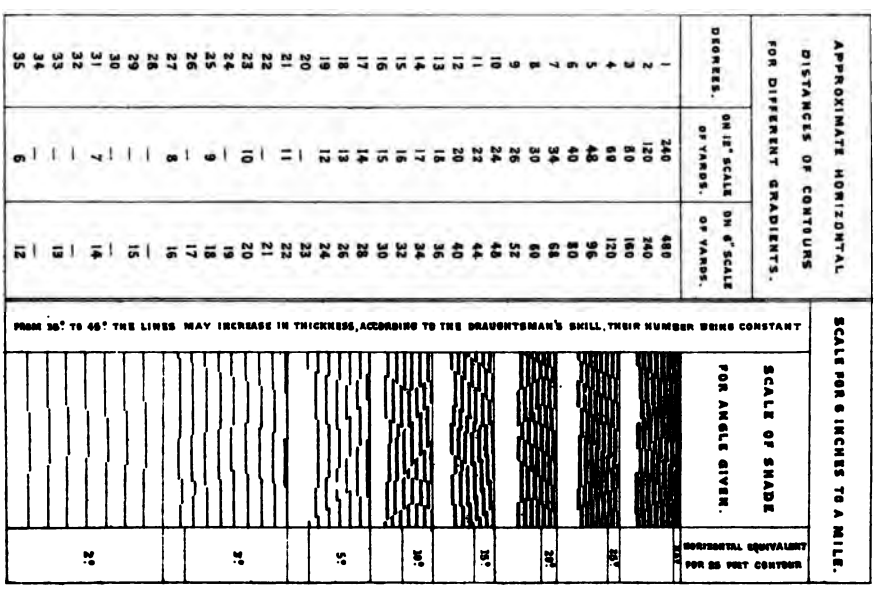
(Plate II.) When an under-feature, in the shape of a knoll,* has to be shaded-in, the block of strokes must first be brought down from the re-entrant AB to the salient DE; then about that extent of shading carried along from the re-entrant FG on the other side to the same salient DE. From the point where the last strokes meet at E, the shading must now be carried to the centre of the neck H,* and from I and J the strokes filled in to EH. The shading must then be begun at K, and taken down till the strokes touch, or nearly touch without actually cutting at H, when that extent of shading will in like manner be carried round the knoll as far down as LM. The re-entrants at N and O are

* See section 45.

Sections, 7. 8. 9.



10. 11. 12.



APPROXIMATE HORIZONTAL DISTANCES OF CONTOURS FOR DIFFERENT GRADIENTS.

DEGREES.	ON 12" SCALE OF YARDS.	ON 6" SCALE OF YARDS.
1	240	480
2	120	240
3	80	160
4	60	120
5	48	96
6	40	80
7	34	68
8	30	60
9	26	52
10	24	48
11	22	44
12	20	40
13	18	36
14	17	34
15	16	32
16	15	30
17	14	28
18	13	26
19	12	24
20	11	22
21	11	22
22	10	20
23	9	18
24	9	18
25	8	17
26	8	16
27	7	15
28	7	14
29	6	13
30	6	12
31	6	12
32	6	12
33	6	12
34	6	12
35	6	12

SCALE OF SHADE FOR ANGLE GIVEN.

FROM 30° TO 45° THE LINES MAY INCREASE IN THICKNESS, ACCORDING TO THE DRAUGHTSMAN'S SKILL, THEIR NUMBER BEING CONSTANT

HORIZONTAL EQUIVALENT FOR 25 FEET CONTOUR	
25'	2°
50'	1°
75'	30°
100'	25°
125'	20°
150'	15°
175'	10°
200'	5°
225'	0°

SCALE FOR 6 INCHES TO A MILE.

now begun and shaded downwards towards P and Q, when the strokes are ready to be introduced down as far as RS and TU, so as to embrace both the hills, and afterwards shaded off all round.

The shading of knolls has been found to be such a stumbling-block with beginners, that, in addition to the explanation just given, the different stages in the process have been shown in another form in Plate XIV.

As the work advances the original sketching should be rubbed out, a little at a time, till it is only just visible, in order to give a sharper and cleaner effect to the drawing when it is completed. A convenient method of erasing any mistake in drawing without obliterating more of the work than is actually necessary, is to cut a hole of the required size and shape in a firm piece of paper or cardboard, place it over the spot on the drawing to be rubbed out, and hold it steady whilst using the Indian rubber.

The hills, as a general rule, should be finished first, and the rocks, sand, water, and other details drawn afterwards; except when they interfere with the hills, when they must be worked in along with them.

To insure accuracy, all lines, outline-sketching, and printing should be carefully traced in pencil before being inked-in.

When working in Indian ink, care must be taken to bring both points of the pen to bear equally on the paper, otherwise the strokes will not be of the same thickness throughout.

DESCRIPTION OF THE OROMETER.*

7.—The Scales.

(Plate I.) Several scales in yards and military paces are shown on the orometer.

A scale is the method of expressing the proportion between a drawing and the object which it is intended to represent. The mathematical expression of this proportion is called its representative fraction.

* Orometers sold by the Publishers, and also by H. Savage, Bookseller, Yorktown, near Farnborough, Hants.

The representative fraction of a scale is determined by bringing to the same terms the length on the scale with the equivalent it represents on the ground, and after reducing them to their lowest terms, placing the former as the numerator, and the latter as the denominator of a fraction.

For example, to find the representative fraction or scale corre sponding with 6 inches to a mile: multiply 1760 yards by 36 for the number of inches in a mile, = 63,360, or 6 inches on paper, = 63,360 inches on the ground, and the fraction is expressed $\frac{6}{63360}$ or in the simple form of $\frac{1}{10560}$.

To bring any scale on which a map has been constructed to its equivalent in English miles, all that is necessary is to work out its proportion. State as the distance on the given ground expressed in yards is to an English mile, so is the length of the given scale expressed in inches to the required scale; or it is still simpler to find first the representative fraction corresponding with the scale, and then to state as its denominator is to an English mile reduced to inches (or any other extent of ground for which a scale is required to be constructed), so is its numerator to the length of the required scale in inches.

Take the case of a French plan on a scale of one metre to a kilometre, to find its equivalent in inches. Now state as 1093.63 (the number of yards in a kilometre) is to 1760 (the number of yards in a mile), so is 39.37 (the number of inches in a metre) to the answer, which is about 63.36 inches. The same result will be attained by working from the representative fraction; because, as there are 1000 metres in a kilometre, the representative fraction would be $\frac{1}{1000}$; and stating as 1000 is to 63,360 (the number of inches in a mile), so is 1 to the same answer of 63.36 inches.

If the denominator of the representative fraction is small, it shows that the scale is so very large that the whole could not be conveniently represented; in which case some moderate length which can be shown must be discovered. Supposing a scale in yards, expressed by $\frac{1}{250}$, is required to be constructed; then 250 yards on the ground being the same as one yard on paper, by proportion the length of a scale, say for 50 yards, may be found to be 7.2 inches; which can be subdivided on the same principle as the following scale down to single yards if necessary.

(PLATE II.) To construct a plain scale of 4 inches to 1 mile: make AB = 4 inches, draw AC at any angle to AB, set off 17 equal parts and $\frac{6}{10}$ upon AC, join BC, and parallel to it draw lines through 17, 16, 15, &c. Then will AB become a scale of 1760 yards on 4 inches to 1 mile. In the same way AB may be divided into any required number of parts; for should a scale, for instance, of any special length of paces be required, under the assumption as an example that each pace was to be 33 inches in length, this number would have to be divided into 63,360, the number of inches in a mile, with a result of 1920. The diagonal line would then have to be divided into $19\frac{2}{10}$ parts, instead of as in the previous case of $17\frac{6}{10}$.

Distances are measured off the scales by holding the edge of the orometer in coincidence with the position on the paper, where the distance is required to be marked off; when the scale is not on the edge it must be taken off with a pair of compasses. Ordinary protractors are often provided with surveying scales.

8.—THE PROTRACTOR.

The circle is divided into 360°, and the instrument for laying off these divisions upon paper is called a Protractor.

(PLATE I.) A protractor is engraved along the edge of the orometer, for laying off angles which have been previously observed with some other instrument.

It has been found enough to subdivide it to the extent of degrees, as that is sufficiently near accuracy for the protracting * of any angles which can be observed with the prismatic compass.

On the margin of the orometer are marked angles under 180°, and immediately inside of them those up to 360°.

The parallel dotted lines marked across the instrument are for the purpose of adjusting it on the paper in protracting magnetic angles.

9.—THE CLINOMETER.

(PLATE I.) The clinometer is an instrument for ascertaining the different degrees of the slopes of hills. It is an arc graduated, and numbered in degrees from the centre; which, by means of a

* See section 45.

plummet or pendulum oscillating from the centre of the circle, gives the declination of slope. This plummet must be attached to the orometer through the stringhole, marked by a star, before proceeding to use the clinometer scale.

(PLATE II.) In taking an angle of elevation or depression with the clinometer, the string AC of the plummet retains a vertical position, whilst the instrument is tilted over till the zero on the arc stands in the position of the line AB. Now if a line DC is drawn at right angles to AC, the two angles BAC and BCA of the right-angled triangle ABC will be equal to the right angle ACD; and by taking away the common angle BCA, the angle BAC, marked by the plummet, is left equal to the angle BCD, the extent to which the orometer has been raised or lowered from the horizontal line.

The upper edge of the orometer being consequently brought by the eye into coincidence with the line of sight of the surface of the slope, the number of degrees can be read off; from which the approximate distance of the horizontal equivalent of the contour can be laid down from the table of gradients.

Many different instruments have been introduced for taking slopes, any of which may be employed by the surveyor; always remembering that the simplest which gives the required degree of accuracy is most suitable, as being the least likely to get out of order.

10.—THE COLUMN OF HORIZONTAL EQUIVALENTS.

In the column of horizontal equivalents are the actual lengths of the bases of triangles, with hypothenuses at certain degrees of slope, and a fixed altitude of 25 feet, on a scale of 6 inches to a mile.

(PLATE II.) It was constructed in the following manner:—Draw two lines, AB and CD, parallel to one another, at an interval of 25 feet. In the diagram, for the purpose of distinctness, this has been made six times the size. From the point A in the line AB protract angles, such as 35°, 25°, 20°, &c., and produce them till they intersect the upper line CD. From these last points drop perpendiculars on AB, which will give certain horizontal equivalents, A1, A2, A3, &c., corresponding with the

different degrees of slope. These distances can now be calculated trigonometrically.

The actual distances in yards may also be calculated by the following method :—19.2 yards being the approximate horizontal distance corresponding to 1° of slope at a height of 1 foot; multiply that number by the width apart of the contours and divide by the degrees of slope. For example :—To find the horizontal distance corresponding with 8° of slope for 20 feet contours

$$\frac{19.2 \times 20}{8} = 48 \text{ yards.}$$

The following are the approximate fractions for the ratios of the altitudes to the bases of the different right-angled triangles which are noted in the column of horizontal equivalents.

2°	= $\frac{1}{30}$	15°	= $\frac{1}{4}$
3°	= $\frac{1}{20}$	20°	= $\frac{1}{3}$
5°	= $\frac{1}{12}$	25°	= $\frac{1}{2}$
10°	= $\frac{1}{6}$	35°	= $\frac{1}{1.5}$

(Plate I.) This column on the orometer is used for discovering on a contoured drawing, the degree of slope which exists at any particular point by the width apart of the contours, for the purpose of being able to apply the necessary depth of shade.

11.—The Scale of Shade.

(Plate I.) A certain depth of shade for the expression of different degrees of slope has, for the sake of uniformity, been adopted for the army. It is independent of the height of the hill, and was fixed entirely arbitrarily from the thickness and distance apart of the strokes which were found to be used to represent ground by most military draughtsmen. Over 35° being considered far beyond the possible limit of manœuvring slopes, it was decided to be unnecessary to carry it higher.

Table

showing the Number of Strokes per inch, and the Thickness of the Strokes employed in the Construction of the Scale of Shade :—

Angle of Inclination.	Number of Strokes per Inch.	Thickness of Stroke.
35°	32	$\frac{1}{50}$ inch.
25°	32	$\frac{1}{70}$ "
20°	30	$\frac{1}{90}$ "
15°	28	$\frac{1}{110}$ "
10°	24	$\frac{1}{150}$ "
5°	18	$\frac{1}{220}$ "
3°	14	$\frac{1}{300}$ "
2°	10	$\frac{1}{400}$ "

In the depth of shade for slopes of from 35° to 45° the lines may increase in thickness, according to the skill of the draughtsman, their number remaining constant. Over 45° is supposed to be broken ground. Slopes under 2° will be shown by still wider lines, gradually softened off into the surrounding plain.

Although the scale of the number and the thickness of the strokes is laid down as just explained, as it was necessary that it should be understood, still, in practice the draughtsman does not require to enter further into the subject, as he will find on the orometer, under its proper column, the style of shading he requires for each degree of slope.

From the following explanation the theory of expressing slopes by a universal scale of shade may be better understood. When the scale is 6 inches to 1 mile, contours 25 feet apart, taken with a spirit-level, will fall at the distance represented by the first horizontal equivalent given on the orometer, viz., for 35°; and this slope is then shown on the survey by broken strokes of the same number as those given in the contiguous column to it. The same applies to every other slope on the scale.

If the survey has not been previously contoured by the aid of an instrument, then the inclination of each individual slope must be obtained by means of the clinometer, in order to know the depth of shade to be used from the scale.

To be able to apply this "scale of shade," it follows that if the

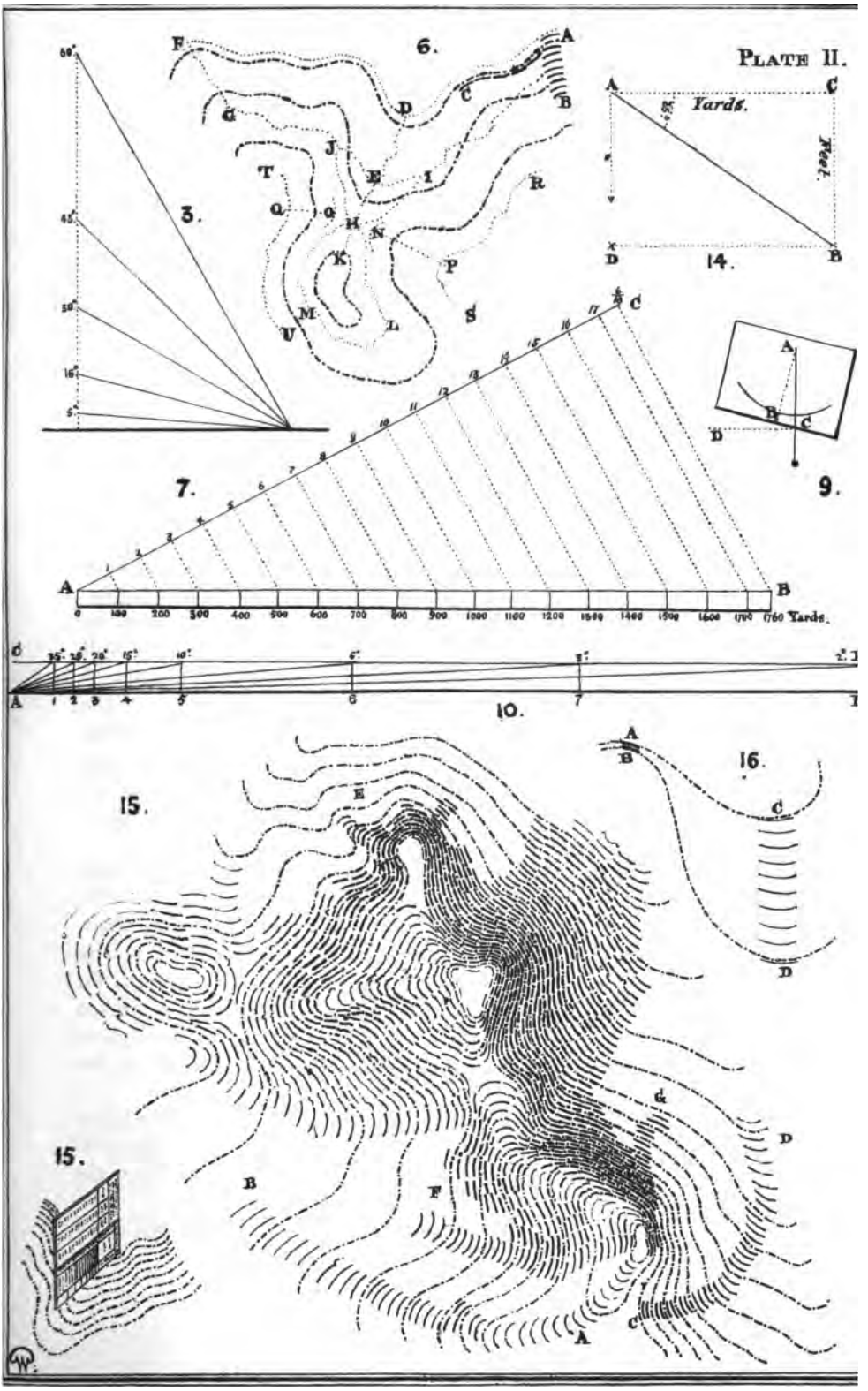


PLATE II.
6.
3.
14.
Yards.
Feet.
9.
7.
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1760 Yards.
10.
15.
16.

6-inch scale itself is not employed, then either some multiple of it must be used, or the proportionate width of contours on the scale required must be discovered. If a 12-inch scale, for instance, were used, two contours would consequently have to be run round the hills for every fall of 25 feet, before the scale of shade could be applied, and so on for every other multiple; but the simpler plan would be, if 25-feet contours were not insisted on, to find the vertical distance by proportion, whether the scale is a multiple or not of the 6-inch scale. Thus, should the contours for an 8-inch scale be required, state as 8 inches are to 6 inches, so are 25 feet. The result would be $18\frac{3}{4}$ feet; and so on for every other case.

The alteration of the scale of a survey has no effect on the thickness of the strokes or their distance apart, but alters the number of the strokes between contours of the same vertical interval, in a direct ratio with the scale.

A scale of shade for stumping * has been introduced, which, without attempting such rigidity to rule as that laid down for hachuring, gives a general guide for the shading of drawings.

12.—The Table of Gradients.

(Plate I.) The approximate distances of the horizontal equivalent for different gradients † have been arranged in a tabular form. In one column are given the width apart of $12\frac{1}{2}$-feet contours, on a scale of 12 inches to a mile; in the other the width of 25-feet contours on a scale of 6 inches. These distances will be found to correspond on the respective scales with the actual spaces laid down in the column of horizontal equivalents on the orometer; for instance, 5° on the 12-inch scale of yards will give a horizontal distance of about 48 yards, the accuracy of which can be tested by measuring it on the column of horizontal equivalents for 25-feet contours.

As a 25-feet interval would naturally cover double the surface of paper if placed at the distance on a 12-inch scale, than it would on a 6-inch scale, it is found convenient to mark the intermediate interval corresponding with a $12\frac{1}{2}$-feet contour at once, when working on a 12-inch scale. Should the survey be on

* See section 119. † See section 45.

an 18-inch scale, another column of distances, representing 8⅓-feet contours, would have to be laid down. Naturally in the same way, if the scale required were 3 inches to a mile, 50-feet intervals would have to be inserted.

The gradients for any scale can be calculated by proportion. If those for the 4-inch scale were wanted, state as 4 inches are to 6 inches, so is 480 (and every other distance corresponding to the degrees on the orometer) to the required result.

The reason for the introduction of intermediate or any other contours, is in order that the one column of horizontal equivalents given on the orometer may be utilised in shading a drawing on any scale. When the contours have once been inserted at two, three, or any number of parts of 25 feet, according as the scale is double, treble, or any other multiple of 6 inches, or even when once established at the proper distance, although independent of bearing any proportion to that scale, all difficulty is obviated in applying the one scale of horizontal equivalents; as these contours then become the true guide to the proper number and distance apart of the strokes from the scale of shade, without any further reference to the scale on which the drawing is being executed.

Without precluding the adoption of any vertical interval which might be most convenient, it will be found that the introduction of a 10-feet interval for a 12-inch scale, with its appropriate multiples of 20 and 40 feet for 6 and 3 inches, are still more desirable than those at present in use; therefore the table of gradients for the first of these is hereunto annexed, from which the others can be calculated if necessary.

Degrees.	10 Feet-Contours in Yards.
1	192
2	96
3	64
4	48
5	38
6	32
7	27
8	24
9	21
10	19

Degrees.			10-Feet Contours in Yards.
11	.	.	17
12	.	.	16
13	.	.	15
14	.	.	14
15	.	.	13
16	.	.	12
17	.	.	11
18, 19	.	.	10
20, 21	.	.	9
22, 23, 24	.	.	8
25, 26, 27	.	.	7
28, 29, 30, 31, 32	.	.	6

SHADING CONTOURS.

13.—Definition of a Contour.

A contour is a line representing the intersection of a horizontal plane with the surface of a hill; every point upon it will consequently assume the same vertical elevation. In military surveying the sphericity of the earth is not taken into account.

The comparative heights of hills are shown by a series of these contours at certain fixed vertical intervals, and in plans which are not shaded the contours alone will show the general configuration of the ground.

A contour cannot form a salient * bend under a re-entrant * one,

* See section 45.

for then the drainage would have to pass down the ridge of a water-shed.* It cannot pass from one side of a neck * over to the other, for then it would not retain the same level. It cannot cut another contour, for then it would stop abruptly.

It has in the meantime been determined that contours of 10 feet apart shall be the proper interval when the scale is 12 inches to a mile, and that the scale shall always be either 12 inches to a mile, or a convenient multiple or measure of that scale, which forms the basis of the present scheme of shading. As already directed, they should be indicated by coloured chain-dotted lines, or, if preferred, continuous lines.

14.—Contours by the Slopes instead of the Vertical Intervals.

(Plate II.) To lay down true contours, a succcssion of points is ascertained by levelling;* but a quicker method has been devised of merely taking the angle of the slope, and reducing it to its horizontal equivalent, applied from a certain scale. This is a much less laborious process, and therefore better adapted to military purposes than that of ascertaining the height with a spirit-level; although the result in both cases is theoretically the same.

In the one instance the declination of the slope AB is taken with the clinometer, for the purpose of being able to apply at once the horizontal equivalent DB from the orometer; whereas in the other case, the vertical interval CB is found with a level, in order to ascertain the space to be measured above the surface of the slope, and eventually to reduce that distance to its horizontal equivalent, AC, which is equal to DB.

15.—Method of Applying the Orometer.

(Plate II.) Certain preliminary guiding strokes have to be laid down on all the more important salients and re-entrants between each set of contours, by finding on the drawing such distances as correspond with the different horizontal equivalents on the scale, the edge of the orometer being held at right angles to each pair of contours in the manner shown on the smaller diagram for this

* See section 45.

section, and transferring to the paper from the proper column the exact number as well as thickness of the strokes, in the way shown in the larger diagram at AB and CD.

If a drawing is to be shaded in ink, the guiding strokes should in the same way be first marked in pencil, and then the orometer being placed on the paper in front of the draughtsman for general reference, the drawing can be completed in ink over the whole sketch, beginning of course at the higher ground.

Should the strokes be worked-in continuously, it will be found impossible to apply the true shade from the scale; but they must be formed as represented on the orometer.

(PLATE II.) On passing over one contour, the eye should be immediately directed to the next, with the view of gradually bringing the direction of the strokes from the curve of the one contour to that of the contour immediately next below it. Although the actual falling of the strokes on the top of the contours will be accidental, still they must lie on the paper in the exact curve of true contours, without cutting them at an angle in the slightest degree, as shown at E, F, and G.

When a change takes place in the depth of shade, the strokes must be blended gradually into one another, and not left in a succession of abrupt steps, which do not exist in nature.

16.—REASON FOR BREAKING THE STROKES.

(PLATE II.) It will be noticed that the number of strokes is not constant between each pair of contours, but, as at AB, the proper number from the scale for 35° is 2 strokes, whereas at the next point, CD, where they have been marked, the number was 10 for 2°. This of course consequently applies in a modified degree to every intermediate degree of slope. Now if 2 is exactly the proper number at AB, it cannot be the proper number for the very next set of strokes, and the successive rows afterwards will in like manner vary in number in working towards CD. It has consequently been found in practice, that the only convenient way to get rid of the difficulty of not letting it be seen where an extra stroke has been taken on or decreased, so as to preserve a uniform appearance in the shading, and at the same time to work by the true scale of shade, is by never allowing the strokes to follow horizontally.

It will be seen that this has been done on the orometer from which the strokes are to be copied, but in addition it will be noticed that they are very much broken on the steepest slope and gradually made rather less so on the gentler ones. Their proper length for each slope has also been laid down on the orometer.

DRAWING SECTIONS.

17.—Definition of a Section.

Sections are the representations in profile of the intersections of vertical planes with the surface of a hill.

After the vertical plane has cut through the features of a hill, if it were supposed that the rest of the ground nearest the observer could be removed, the result would be to expose a certain irregular profile, giving the line of contact which is represented in the construction of sections.

It is of importance that a proficiency in drawing them should be attained for the purpose of acquiring a thorough knowledge of the formation of the features of ground, as they form the crucial test of being able to read ground, the draughtsman either actually constructing on paper a section along the line indicated, or at all events, carrying an impression of it in the mind.

18.—Assumption of the Datum Level.

A datum line is the level with which all other heights are relatively compared.

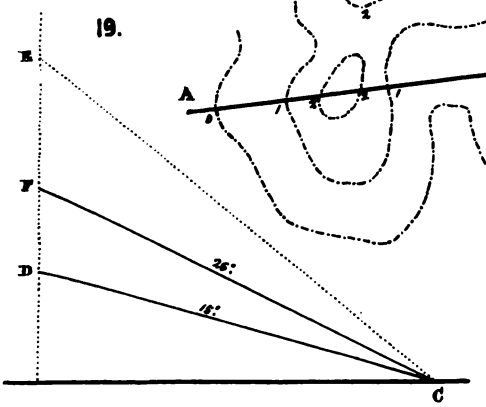
In levelling over a large tract of country the mean tide level of the sea is taken as the datum level.

Sometimes it is assumed at 100, 500, or 1000 feet below the lowest point of the ground surveyed. If not otherwise stated, it is taken as represented by the lowest contour; or where any large sheet of water exists on the lowest ground, then the surface of it is taken as coinciding with the datum line.

Unless the datum is assumed below the lowest contour it will not be possible strictly to represent the sectional line at any points where it may cut below that contour, unless it happens to be a plane; but where the object is only to give an idea of the

PLATE III.

19.



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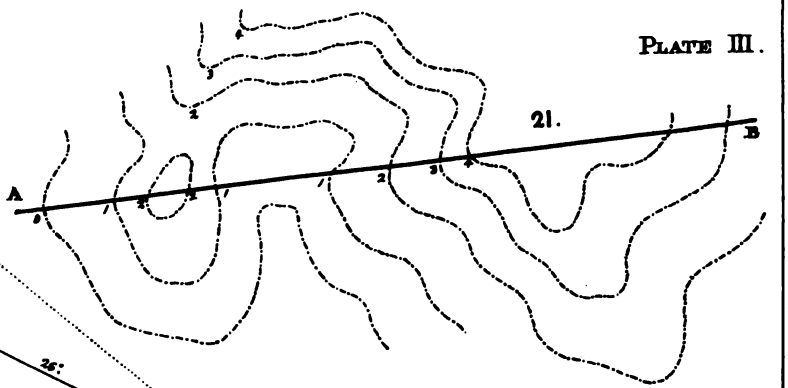

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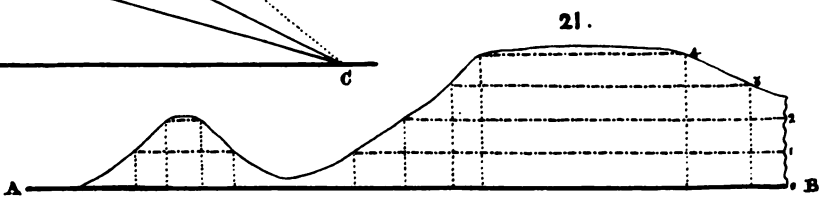

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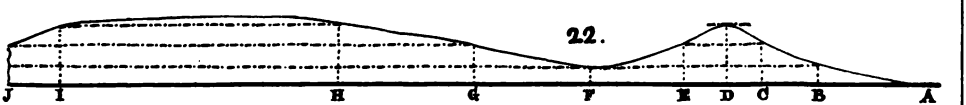

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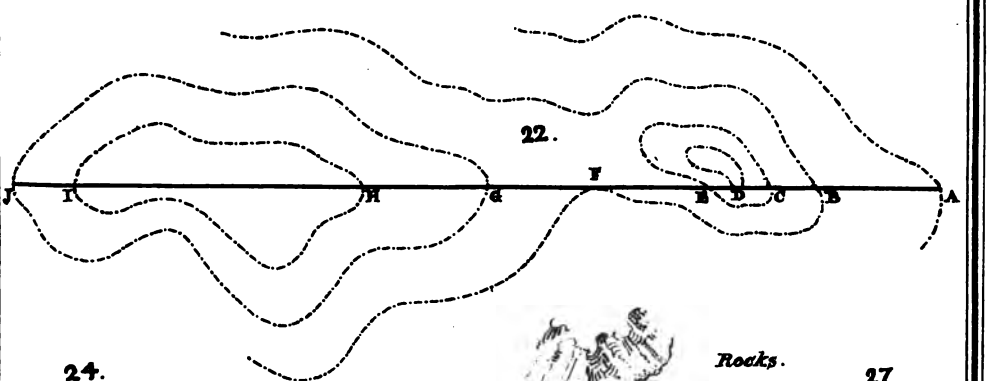


24.

27.

Rocks.
Sand.
Water.
Navigable } *River.*
Unnavigable } *River.*
Anchorage.
Soundings.
Trees.
Marsh.
Common.

comparative heights of the hills on a drawing, this is not of much consequence.

19.—Exaggeration of the Vertical to the Horizontal Scale.

Although the distances are generally made the exact size of the scale of the drawing, yet the heights are always exaggerated for the purpose of conveying to the mind the impression of sufficient elevation, which is not otherwise attained.

(Plate III.) To prove that this is the case, the line CD has been protracted at the true inclination of slope of the general run of upper-features in the vicinity of the Royal Military College; whereas it would require an elevation of about CE to convey a proper impression of the steepness. The slope CF is the very steepest which has yet been found on the surveying ground, and it even only exists at two points, and that for a very short distance. It is very difficult to walk upright in ascending at these points.

This exaggeration of the vertical scale is expressed as the relative heights to the distances, and when not distinctly stated, is generally assumed on military plans as at 3 to 1.

20.—Requisite Conditions with the Necessary Calculations.

In the case of a contoured plan it is necessary that three conditions should always be given for the purpose of making a section of the ground on any proposed line:—

1st. The vertical width apart of the contours.
2d. The relative heights to the distances.
3d. The scale on which it is to be drawn.

Let us suppose a case with the following conditions:—

Contours 25 feet apart.
Heights to distances as 3 to 1.
Scale, 12 inches to 1 mile.

Divide a 25-foot contour by 3, to bring it to yards, as there is no scale of feet on the orometer. This gives $8\frac{1}{3}$ yards. Multiply by 3 to obtain the relative heights to the distances; the result is 25 yards on a 12-inch scale. If the draughtsman has no 12-

inch scale with him, he will now have to multiply again, for instance, by 2 to bring it to a scale in his possession. The result is 50 yards on the 6-inch scale, which will stand in figures as—

Contour, 3)25 in feet.
$8\frac{1}{3}$ in yards.
3
Exaggeration, 25 yards on a 12″ scale.
2
Parallels, 50 „ 6″ „

Consequently, a succession of lines 50 yards apart must be drawn above and parallel to the datum line, as has been done in one of the diagrams to Section 21.

Should a case arise in which the scale given for the section neither corresponds with one on the orometer nor is a multiple or measure of one; then the draughtsman will have either to construct the actual scale for himself, or, more simply, find by proportion the one distance which he requires for the width between the parallels. For instance, supposing the conditions for making the scale to be 15 inches to a mile, and that the distance was found to be $53\frac{1}{3}$ yards, it would be necessary to state as 12 inches are to 15 inches, so are $53\frac{1}{3}$ yards to the answer; which gives $66\frac{2}{3}$ yards as the distance to be measured on the 12-inch scale for the width of the parallels above the datum line. Twelve inches was here selected merely because it was supposed to be a convenient scale in the draughtsman's possession. In the proportion the 12 was placed before the 15, to form an inverse ratio; because there would naturally be shown more yards on a smaller scale, or, in the opposite case, there would be fewer yards to be taken from a larger scale.

To avoid the complication likely to arise in sliding for these lines with the marquois scales, which instruments are described in Section 65, it will be found desirable merely to dot off a succession of points immediately above each end of the datum line, and to join the parallels through them.

If, in making a section, the width apart of the contours is not actually stated, it must be concluded that their proper width for the scale given is intended.

A constant source of error is that of not remembering that the contours are always given in feet, whereas all the scales are in

yards. It is therefore advisable always to begin the calculation for the width apart of the parallels by bringing the feet into yards.

21.—Construction of Sections from a Plan.

To make a section from a contoured plan it is better to begin by numbering the contours from 0, 1, 2, 3, &c., upwards, in order to prevent confusion, and having drawn a datum line on any convenient space on the paper, to place corresponding numbers on it, and the parallels above it, which are presumed to have been laid down as directed in Section 20.

(Plate III.) Suppose AB to be the line of intersection of a vertical plane with the contours of a plan, lay down the edge of a piece of paper along this proposed sectional line, and dot off on it the intersection of each contour with the vertical plane. Transfer these points to the datum line, and from them raise in succession perpendiculars to intersect the proper parallels.

(Plate III.) From the point A as the lowest ground follow out the sectional line as the perpendiculars and parallels may direct.

In tracing the curves of the section it is necessary to remember that in going straight up the face of a slope the outline will be concave, in going over a spur it will be convex, and, consequently, in ascending diagonally, as the intermediate sectional planes to the two extreme cases of convex and concave will naturally produce intermediate results of the same description though varying in degree, it will be more or less a straight line. Also, that according as the line of vertical intersection passes at a certain proportional distance between any two contours, without cutting them, so will the section be drawn at that relative distance between the numbered parallels which represent these contours.

When finished, the contours and the parallels within the section should be inked-in in chain-dotted lines,—the vertical intersection and datum lines in continuous thick lines,—the sectional line in a thin continuous line,—the perpendiculars in small dotted lines, and the calculations printed alongside.

To make a section of a plan on which the precise heights of the hills are not shown, either by contours or marked in feet

above some particular level, all that is necessary will be to dot off on the edge of a piece of paper the points where the different breaks in the slopes are intersected by the vertical intersection line; and after these are transferred to the datum line to show the points above which the changes of slope are to take place, decide on the height which would represent the highest hill, mark off the comparative heights of the others, and trace the sectional line through these points in the same way as has just been explained for a contoured plan. A section on this principle has been shown in Plate XV., of the line of railway passing through Longdown Hill, which has been previously drawn in Plate IX. Where the heights of some of the hills are marked on the plan, the altitudes passing near the line of vertical intersection will settle the comparative heights on the section.

22.—Section from Contour Measurements, and Plan from Section.

(Plate III.) It will be found desirable for the draughtsman to take such examples as the following, in order to acquire facility in this part of the subject.

To construct a section on a 6-inch scale from the following measurements taken from a contoured plan, making the heights to the distances as 4 to 1.

From	To	Contour of 25 feet.	Distance in yards.
A	B	Rise	175
B	C	"	80
C	D	"	40
D	E	Fall	60
E	F	"	150
F	G	Rise	165
G	H	"	200
H	I	Level	410
I	J	Fall	97
		Total...	 1377

(PLATE III.) After the preceding section has been drawn from the given measurements, the draughtsman should try to lay down a possible plan of the contours from which it was constructed. Diagrams of both will be found among the plates.

The following conditions for practising sections will be found suitable, where the drawing from which they are to be taken is of a moderate size.

Direction.	Scale.	Contours.	Heights to Distances.
A, B	12 inches	10 feet	5 to 1
C, D	16 „	15 „	4 to 1
E, F	18 „	12½ „	3 to 1
G, H	24 „	20 „	2 to 1

MODEL DRAWING.

23.—METHOD OF DRAWING UNCONTOURED MODELS OF GROUND.

Preparatory to going out surveying, sketching from models of ground is of the utmost importance; especially if the training is carried out on uncontoured models, as on them the draughtsman will be compelled to trace out the features from their sources and join them in their proper order, thus giving him a thorough knowledge of their construction, which is not the case when the study has been carried out on contoured models. The drawing should be made at first exactly the same size as the model.

Models are generally cast on a larger scale than would be used for ordinary surveying, in order that the features may be well defined for the purposes of study; their heights are also much exaggerated.

For private practice in model drawing, when access to regular casts cannot be obtained, flint stones can often be found giving a very fair idea of the forms and junctions of hill features.

The different processes of copying them must be carried out as strictly as in the case of drawing plates: these have been detailed in Section 5. The eye must invariably be directed in succession from immediately above each point of the model which is being drawn.

24.—Preliminary Outlines.

A succession of points should be taken by measurement, by off-set * as most convenient, to assist in tracing-in the outline in the order stated in the first part of Section 5 with reference to drawing plates. This is done after the boundary has been laid down on the paper, by taking measurements at right angles from each two contiguous sides of the model to all the more important points, and by means of these measurements applied to the drawing paper from the corresponding sides of the boundary line, settling the respective positions of the required points. The intermediate parts are then traced in by the eye.

(Plate III.) When the position of the crest * of each hill is decided on, the distance must be measured down to the beginning of every principal change of slope, which must then be marked, and from which the declination of the fresh slope must be taken with the orometer, in order to decide on the requisite depth of shade. These degrees of slope should be entered in figures on the drawing before the shading is commenced, as has been shown in the diagram. By thus working by the slopes instead of the contours, the one scale of shade can at once be applied to any scale on which a drawing is to be executed.

Before beginning to work-in, the general sketching and contours ought to be outlined by marking the upper edge of each change of slope as accurately as if it was taken from a copy, and each successive step should be completely executed before proceeding to the next. The outline will look larger to the eye than the model, although it may nevertheless be accurate.

25.—Shading and Junction of Under to Upper Features.

The darker shading should be continued well down each slope before the lighter shading is begun, and it will be found that it will generally be a little lighter in the re-entrants than at the salients.

The lower features should be followed out from the re-entrants* on each side; the shading being always worked from the re-

* See section 45.

entrants to the salients. The reason for carrying the shading in this direction is, that in going down the hill the draughtsman is almost always working from a steeper to a more gentle slope, which implies an increased width apart in the contours, a consequent greater extent of surface to be covered with shading, and therefore a greater number of strokes. It will be found that it is a comparatively easy process to take on strokes, whereas if the work was taken from a salient up to a re-entrant, the strokes would constantly have to be diminished in number, a much more troublesome operation in practice.

It will be easily seen that the strokes will have a tendency to get shorter in the re-entrants and longer in passing round salients, so as to make them fit more naturally into one another.

(Plate XIV.) The junction of a knoll to its upper-feature must be executed as detailed under Section 6, care being always taken to bring the two higher slopes down first, till the projecting strokes nearly touch; the re-entrants on each side of the neck being always separated from one another, with, in most cases, a small blank space on each side above each re-entrant.

26.—Assimilation of Processes to those Carried out in Surveying Ground in the Field.

In studying models advantage should be taken to assimilate the work as far as possible to the process of surveying out of doors, as, unless a good knowledge of the natural formation of features is obtained from models which can be handled and turned to every suitable position, the beginner is obliged to attempt the much more difficult task of learning model-drawing from the features of the ground whilst field-sketching; and thus, instead of being able to seize the mass of features before him and study their connection with each other, he can only see them, until his eye is properly trained, in an isolated way, which is comparatively useless.

CONVENTIONAL SIGNS AND DETAILS.*

27.—Rocks, Sand, Water, Trees, Marshes, and Commons.

(Plate III.) Although no effect of light and shade is admitted in the representation of hills, still, in order to give a proper expression to most of the conventional signs in military plans, the light is supposed to come in from the upper left-hand corner.

Rocks are drawn very much the same as in landscape-drawing, only that it must be kept in view that the light is falling on them from the left, and that the opposite side will necessarily be darker than the other.

Sand is shown by very small round dots, gradually shaded off towards the land.

Sheets of water are represented in the horizontal system of shading hills by fine horizontal lines, close together round the shore, and widened as they recede from it; sometimes the closer lines are only put in where the shadows of the land would be thrown upon the water. Rivers are shown by continuous wavy lines, which should be begun at the sources, and the bed of the stream gradually increased as it flows downwards. When navigable they are shown by a double line; when unnavigable by a single one, except when the scale is very large. When a double line is used, the bank next the light should be made thicker than the other. A small arrow should be placed pointing downwards to show the direction of the stream, an anchor where there is suitable holding ground for ships, and small figures showing the depth of water in fathoms where it is known.

Trees are worked-in very much the same as in landscape-drawing, the outer edges being well broken, and the shading hatched in short curved lines. To avoid the surface of the hills appearing confused, the trees, where they exist, are generally put in detached clumps, with the shadows thrown to the right; or merely the word "wood," or "plantation," printed on the surface.

* The sketch of the Road Reconnaissance in Plate X. contains examples of most of the conventional signs here mentioned, worked into the appropriate positions which they would occupy on a plan.

28.

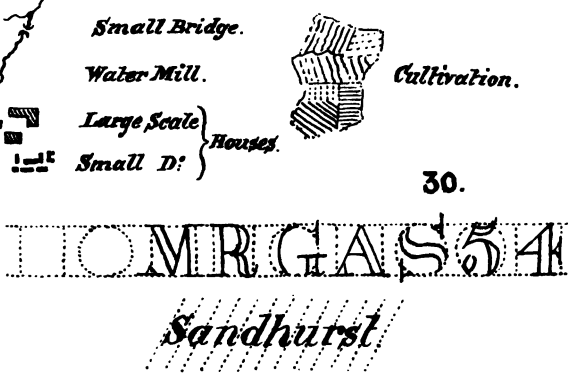
Main Road.
Cross Road.
Roads without hedges.
Footpath.
Ferry.
Ford.
Railway.
Large Bridge.
Small Bridge.
Water Mill.
Large Scale } Houses.
Small D: }

Special Houses.
Churches.
Gravel Pit.
Quarry.
Cutting.
Embankment.
Tunnel.
Canal Lock.
Cultivation.

29.

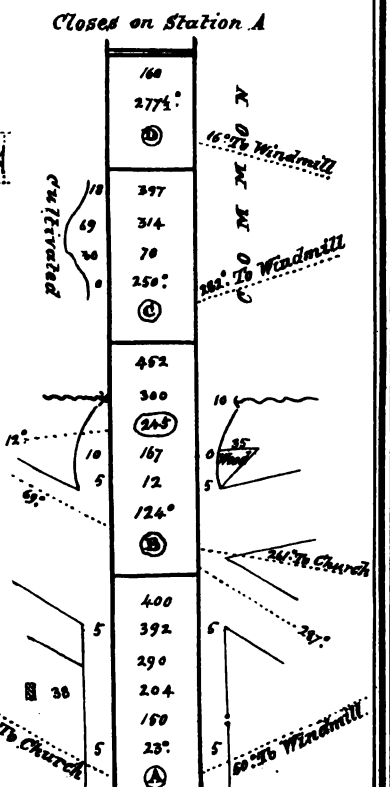
Infantry
Cavalry } Troops.
Encamped
Artillery.
Field-Works.
Abatis.
Telegraph.

30.



31.

Closes on Station A



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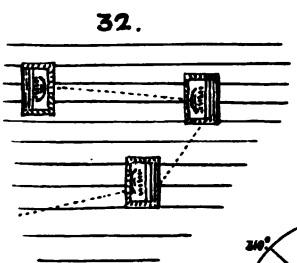

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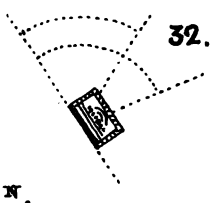

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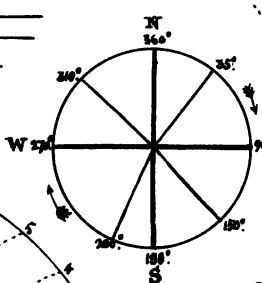
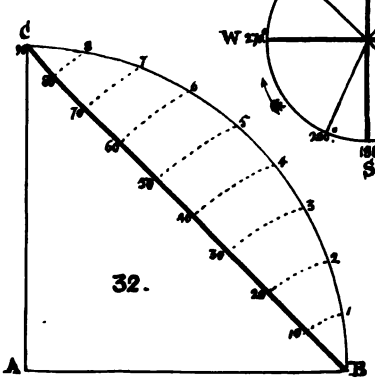
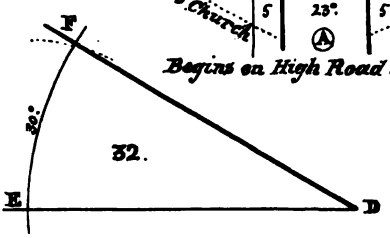




32.



32.

In putting in marshes or commons, the general direction of the strokes must be kept strictly horizontal: in the case of the former, water and tufts of rushes are depicted, in the latter, tufts of grass; but in both cases the attempt must be made of giving nothing more than a slight idea of their existence.

Should it at any time be required to tint the details, it may be held as a general rule that all objects should be represented as like their natural colours as possible, viz.—

Rocks	. .	brown.
Sand	. .	yellow.
Water	. .	blue.
Trees	. .	different shades of green.
Marsh	. .	blue and green.
Pebbles	. .	brown dots over yellow.

28.—Roads, Bridges, Houses, Embankments, Excavations, Tunnels, and Cultivated Land.

(Plate IV.) Care must be taken to keep the lines representing the sides of roads of the same thickness, and generally parallel to one another. Main-roads are represented by making the lower or right-hand side thick; cross-roads by two thin lines; and all roads without hedges, walls, or banks by dotted lines. Footpaths and ferries are shown by a single dotted line, and fords by two dotted lines. Railroads have a thick line for each set of rails, with the fences on each side given as in cross-roads.

The dimensions of bridges must be exactly shown; as on the width of the narrowest bridge on a road depends the frontage of troops and consequent rapidity of their advance. When of a moderate size, they are drawn by two lines parallel to their sides, with the ends bent outwards towards their extremities; if of a smaller construction or less stability, two small curves are drawn back to back in order to represent them.

In drawing buildings, the individual houses must generally be represented by perfectly rectangular blocks. On a large scale they are drawn at first open in the centre, then filled-in with thin diagonal lines, and finished by darkening the right and lower sides; on 6 inches, or any scale under that, they are put in dark

blocks. Buildings erected for any special purpose, such as lighthouses and windmills, are sometimes shown by perspective views of the objects themselves; churches are, however, an exception to this rule, as they are always marked by a cross: also watermills, which are shown by a small circle with lines radiating from it to express the floats of the wheel.

Gravel-pits, quarries, cuttings, embankments, terraces, or in fact artificial depressions or elevations of any kind, are depicted with attention to the usual rule of the light falling on them from the upper left-hand corner. They are shaded in vertical strokes; in the former three cases these strokes would be more or less broken, in the two latter cases they would be quite regular, as would generally be the case in nature.

Tunnels have their entrance arches drawn, and their direction shown on the surface by two dotted lines. The locks of a canal are given by the position of the gates when shut.

Cultivated lands should not be too prominently marked out, although the draughtsman should still try to give an idea of the ridges and furrows of the surface, or the crops and pasturage that may be growing on the different fields. He may also merely print the word "cultivated" within the boundaries.

The following tints may be employed:—

Roads	light brown.
Railways	light red.
Houses, brick or stone .	red.
„ wooden . . .	black.
Land, ploughed . . .	brown.
„ crops . . .	yellow.
„ pasturage . . .	green.
„ heath . . .	purple.

For special plans of any description the following colours are generally used, and the tints laid on before the outlines are coloured.

Brickwork . . .	red.
Stonework . . .	grey.
Woodwork . . .	brown.

29.—Troops, Artillery, Field-Works, and Telegraphs.

(Plate IV.) Troops must be made perfectly rectangular,

whether they are in line or column. Encamped troops are marked with a diagonal line, and troops in action merely with a plain square: a thick line denotes the front of troops. Cavalry have a small flag in front, and when in column are made deeper than they are broad. Sentries and skirmishers are shown by small detached circles. Troops are also sometimes coloured according to the uniforms of the different armies engaged.

Artillery are shown by a representation of a plan of the guns. Artillery in action are drawn with the guns unlimbered.

Field-works will generally be on such a small scale in a military survey, that a line for the crest of the parapet, and perhaps the exterior slope, will be all that can be shown; but if they happen to be on a larger scale, the slopes and ditches must be represented as in fortification. Abatis being formed of the cut branches of trees pointed towards the enemy must be so drawn.

A line of telegraph is drawn in short, thin, vertical strokes at some distance apart, to represent the supporting posts erected along the direction which it takes. When coloured it is shown by a yellow line.

30.—Printing and Line-Drawing.

(Plate IV.) Before beginning printing of any kind, lines should be slid in pencil to insure the uniformity of the tops and bottoms of the letters. The formation of the characters in Roman printing or numerals may be made perfectly regular by reducing each letter to the general outline of a square or circle, as the shape may require. This will be better understood on reference to the diagram. Uniformity in the slope of italics may be secured by sliding pencil lines over the surface to be printed on as a general guide.

To insure the printing of titles, names of scales, &c., being in their proper positions, the letters should first be laid down in pencil from the centre outwards.

All straight lines should be drawn with the aid of a ruler, held across the draughtsman, and when in ink the bevelled edge of a triangle should be used. An even and steady pressure of the pen should be employed, time being given for the ink to flow out of the tire-ligne. It is better to stop short than to overrun any point.

FIELD-BOOK AND PLOTTING.

31.—Form of Keeping Field-Book, with the Different Conventional Entries.

Bearings and distances may either be laid down at once on the survey paper on the ground, or they may be entered at first in a field-book by certain conventional rules, and afterwards transferred to the paper. The second method is principally used when the country is very much enclosed, or where the object is to conceal the fact of a survey being made from the knowledge of an adversary.

(Plate IV.) To illustrate the following description, an example of extracts from a field-book will be found among the plates. The field-book is a note-book with two parallel lines run down the centre of each page, about an inch apart. These lines are to be imagined as touching each other, and to represent the "station-line."* In this centre column, all "stations,"* "forward-angles,"* and "station-distances,"* have to be entered. All entries are made in succession from the bottom of each page upwards, in order that they may follow one another in the natural order of walking over the ground. When the next forward-angle is merely a continuation of the work, a single line is drawn across the centre column; and a double line when the work is to be stopped and begun again at some new point; a note being made to that effect at the end of the one station-line, and a corresponding memorandum at the beginning of the next.

The side entries are made in the outside columns, and are in every case the distances at right angles from the station-line to the sides of the road, houses, and other objects. All points of any importance laid down in these outer columns should be represented by a general sketch of the object they are intended to mark.

With the exception of forward-angles, all angles to objects and directions of roads are traced from the point from which they were observed, by a line drawn in the general direction of that object from the station-line, without reference to its magnetic

* See section 45.

bearing, and the number of degrees are written along it. If taken from an intermediate point, not a station, a circle should be drawn round the figures which show the distance from the last station.

The stations should be numbered or lettered to avoid confusion, and it must be remembered that distances in the centre column are always measured from the last station.

32.—Laying Down Angles with the Protractor and the Scale of Chords.

(Plate IV.) To lay down magnetic bearings,* the ungraduated edge of the orometer is adjusted north and south by means of the coincidence, more or less exact, of the parallel lines upon it with parallel east and west lines already prepared on the paper; the arrow head at the middle of that edge of the instrument being laid upon the point from which the angle is to be laid off, as in the first diagram for this section. Some draughtsmen prefer working with the parallels used as north and south lines, but as the object is the same the practice is immaterial.

(Plate IV.) All magnetic angles are read from the meridian * by east through south and west, so that all under 180° will fall to the right, and all above that number to the left. The orometer must consequently be adjusted to the right of the point if the angle is less than 180°, and to the left if over that angle. The circular diagram may tend to fix this in the memory, the draughtsman considering his position as at the centre of the circle.

When a case arises in which the angle to be laid down comes off the edge of the paper, by reversing the protractor to the other side of the point, and producing the opposite angle, the direction required can be ascertained.

(Plate IV.) If it is required merely to lay down the position of a line with reference to its angle with another contiguous line, as is the case with angles taken with the pocket-sextant,† then the orometer is made to coincide with the given line at the required point, and the number of degrees is marked off upon the paper from that point, as in the upper right-hand diagram.

(Plate IV.) Angles between any two lines are also sometimes

* See section 45. † See section 38.

laid down by means of a scale of chords which is constructed in the following manner :—From the point A draw a quadrant, cut by the radii AB, AC. Divide the arc BC into nine equal parts, each of which will represent 10°. Join BC, and with a pair of compasses from B as a centre, with the distances 1, 2, 3, &c., on the arc, lay off B 10, B 20, B 30, &c., on the line BC. BC will be a scale of chords reading to 10 degrees. By subdividing the arc BC into ninety parts, a scale for single degrees can be obtained.

(PLATE IV.) To set off an angle from a scale of chords :—Open the compasses to the extent of 60° upon the line of chords, which is equal to the radius of the circle, and setting one foot of them upon D in the line DE, describe an arc EF cutting DE in E. Then, taking the extent of the required angle from the same line of chords, set it off from E, cutting the arc in F. Join DF. Then EDF is the required angle.

33.—VERNIER SCALE.

This scale is a contrivance for measuring parts of the space between the equidistant divisions of a graduated arc. It may be made to slide along the arc of any instrument on which it is required to obtain very accurate and minute subsidiary divisions.

When great accuracy is required, the in-door plotting is sometimes laid down by the aid of a circular protractor carrying a vernier scale on its index-arm, by which minutes or even smaller parts of a degree may be plotted. The vernier scale is constructed in the following manner :—

(PLATE V.) Supposing the line AB to represent 30 half degrees on any instrument, let the line DE be made equal to AC, or 29 of these half degrees, which, by the process explained in Section 7, divide into 30 equal parts. The lines DE, AB, being in length to one another as the numbers 29 to 30, which lines in their turn have been subdivided into an equal number of 30 parts, the proportion of each division on DE will be to a division on AB as 29 to 30 ; or each division of the vernier DE will be $\frac{1}{30}$ less than half a degree, that is 1 minute. The number of minutes will consequently be denoted by the coincidence of two lines, after the arrow of the vernier has moved past a degree or half-degree division.

The following may be taken as a formula for the construction of all verniers :—

1. Observe the extent to which the degrees are already subdivided on the instrument.

2. Note the limit down to which they are required to be read.

3. Find how often this limit is contained in a degree, and divide it by the number expressing the parts into which the degrees are divided on the instrument.

4. Take the quotient, minus one part, and subdivide the distance into the full number of parts expressed by the quotient.

5. Each of the latter spaces will be a fraction of the original subdivisions on the instrument, equal to the required limit of the vernier.

Example :—

1. An instrument is already divided into quarter degrees.

2. It is required to construct a Vernier reading to half minutes.

3. There are 120 half minutes in a degree, which, divided by 4 (quarter degrees), gives 30.

4. Take 29 of these parts and divide them into 30 spaces.

5. Each of the 30 parts on the Vernier will give $\frac{1}{30}$ of $\frac{1}{4} = \frac{1}{120}$ of a degree, $\frac{1}{2}$ minute or 30 seconds.

34.—Magnetic Bearings.

The magnetic needle does not point to true north, but varies in different parts of the world, undergoing continual change, and partakes of an annual as well as a diurnal variation. It is at present west in Europe and Africa, but east in Asia and America. In England it pointed due north in 1663, and in 1818 it attained its maximum of 24° 41′ westerly variation. For sometime afterwards it diminished at the rate of about 6′ a year, although latterly in an accelerated degree, even up to 10′ a year, and is now, in 1882, about 18° 20′ west of true north.*

Sir James Ross, in 1831, discovered the position of the magnetic pole to be in latitude 70° 5′ 17″ north, and longitude 96° 45′ 48″ west, by the dip angle of the magnet standing at 90° at that point.

* "Ganot's Physics," translated and edited by Dr. Atkinson, Professor of Experimental Science at the Staff College, Sandhurst.

The reason for laying down the bearing of true north on all surveys, is in order that the sketch may, if required, be joined to other surveys on each side of it, or be itself extended at any future time. To do the latter, the variation of the needle, on resuming work, would have to be ascertained; and fresh east and west parallels be drawn at right angles to the new magnetic north (or north and south parallels corresponding with it), on the blank paper where the more recent part of the survey is to be laid down. As the true north never varies, we have by its means a constant direction to which to refer the relative positions of all objects.

The bearing of the shadow of the sun at noon gives the variation of the compass; or the variation of the needle at any particular place in the northern hemisphere may be very nearly found by taking the difference of the angle of the North Star from the angle observed by the compass.

The prismatic compass is worked from the magnetic meridian, but theodolite angles may have reference to any zero-line at which the horizontal plate of the instrument may stand when the work is begun.

35.—Theodolite.

The Theodolite is the most perfect surveying instrument for taking both horizontal and vertical angles, but from its complexity, costliness, and want of portability, is seldom in the possession of officers. For all practical purposes they find the prismatic compass sufficiently accurate for taking horizontal angles, and in the few cases in which they require vertical angles, they can be taken with the pocket sextant, or, more simply still, with the clinometer scale of the orometer. It will consequently be sufficient to give here merely a general description of the Theodolite.*

The instrument consists of a telescope carrying a small spirit-level resting by supports on a vertical arc for taking angles of elevation or depression, which can be read off on the latter by

* For those who wish for further information on this and other instruments, with their adjustments, reference may be made to a useful manual by J. F. Heather, M.A. "A Treatise on Mathematical Instruments." Crosby, Lockwood, and Co., 7 Stationers' Hall Court, Ludgate Hill.

the aid of a vernier scale. Under these stand a horizontal circle to which is adjusted an index-plate also carrying spirit-levels, and a vernier for taking off horizontal angles. Inside the horizontal plate is placed a compass box for giving the magnetic bearings, and still lower a collar revolves on a vertical axis for turning the parts above it. The whole instrument rests on a tripod stand, to the top of which is fixed a set of parallel plates with levelling screws. Certain adjusting, clamping, and tangent screws are employed for fixing the instrument with the greatest accuracy.

36.—Prismatic Compass, and the Method of Taking Angles.

(Plate V.) The prismatic compass may be looked upon as a simplified theodolite, composed of a magnet and compass card A, supported on a pivot B, in the centre of a cylindrical box C, but with the power of taking horizontal angles only. At one side a prism of glass D is adjusted on a sliding bar E, for arranging the focus; on the other immediately opposite side is a sight-vane F. Both the prism and the sight-vane work on a hinge for the purpose of folding them out of the way when not in use. A small spring checks the vibrations of the compass card, and another throws it off its pivot. The instrument is sometimes mounted on a tripod stand for the purpose of getting it steadier, but it is generally merely held in the hand for the sake of portability; by which arrangement a newly-invented clinometer can be affixed to the reverse.

There is a peculiarity in the compass card, that the numbers are inverted, in order that whilst the eye is looking directly at an object through the sight-vane, they may be refracted to the eye through the prism of glass in their proper positions without losing sight of the object.

To take an angle with the compass, the eye must bring the opening H above the glass prism, the hair J of the sight-vane and the object into one line, when the eye will read the number of degrees from north in the angle. On a windy day when there is a difficulty in getting the compass card to settle, it is necessary to observe the extreme vibrations on each side of the hair of the sight-vane and to take the mean angle between them.

37.—Plotting* the Work upon Paper.

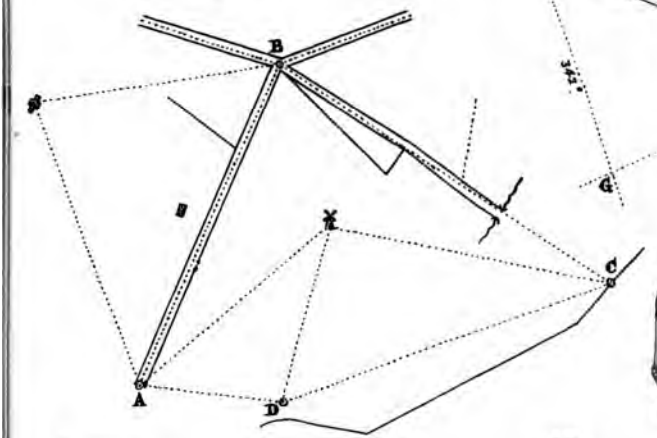
(Plate V.) To illustrate the following description, an example of the work plotted down on an eight-inch scale from the field-book given in Section 31 will be found in Plate V.

The draughtsman being provided with a sheet of survey paper having parallel east and west lines engraved upon it, let him by their assistance, as explained in Section 32, adjust his orometer at any convenient point A which will enable him to get the whole of his work on the paper. From this point let him dot off the angles of 50° to a windmill, 340° to a church, and lastly 23° for the direction of the road on which he is about to proceed. Let him now mark off along the last line, which is his forward angle, from any scale he intends to employ, the distance of 400 yards, being the last entry on that station line. This will give him point B; and having rubbed out any superfluous length of line beyond this point, let him protract the angles 69° for one road, 261° to the church, whose position will now be settled, 287° down another road, and finally 124° for the fresh direction. After laying down 245 yards from the scale along the new station line, some object of sufficient importance to be observed bears 12° from this point, which must consequently be protracted, and then the complete distance of 452 yards laid down from the point B to give station C. From C the angle of 282° must be protracted towards the windmill, and 250° for the direction of D. At D another angle to the windmill settles its position, or its situation, as well as that of the church, having been previously accurately laid down by triangulation, which will be explained immediately, the angles to these objects are now protracted to test the accuracy of thework, by seeing if they strike the points which represent them on the paper. Should they not do so, some error must have crept into the back work which will have to be detected and rectified; and in any case a fresh departure must be taken from the settled point of triangulation instead of accumulating errors. Inaccuracy often arises either from the pacing having been too long or too short; the work not reaching far enough in the first case, from there being too few paces, each

* See section 45.

PLATE V.

37.



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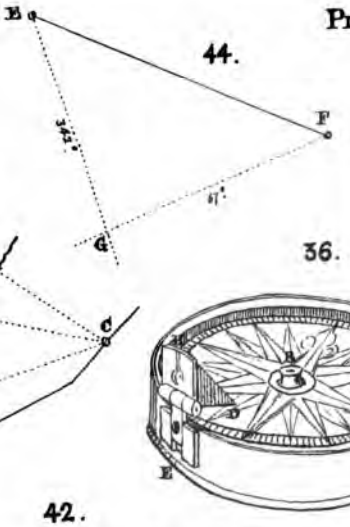

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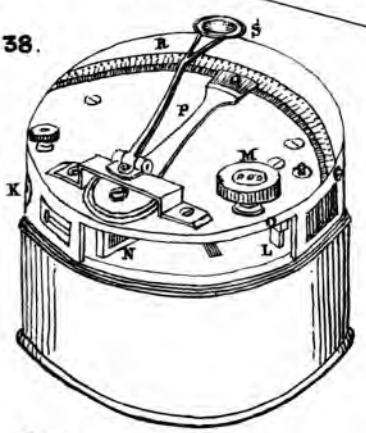

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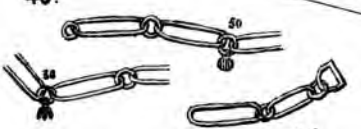

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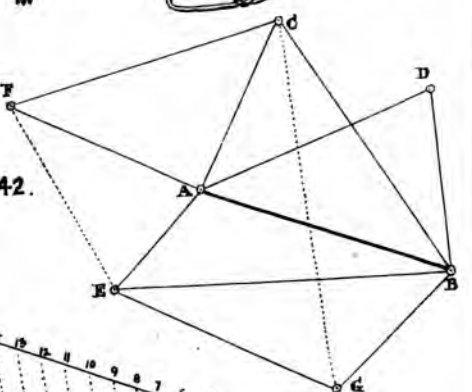

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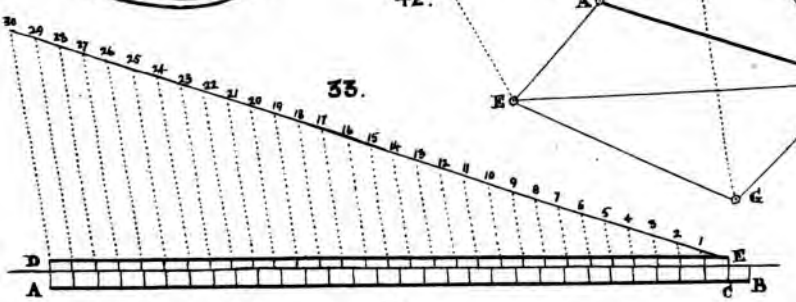

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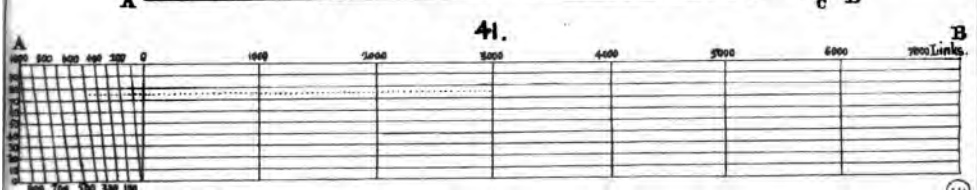


one being too long, with of course a reverse result in the opposite case. On protracting the station line from D it should, if the work is accurate, not only exactly pass through the point A, but the distance of 160 yards should be attained in closing * on it.

The station-lines being now all completed, the draughtsman must return to station A and mark off 5 yards on each side of the line AB for the sides of the road; at 150 yards a gate in the right hedge; at 204 yards a house standing 38 yards to the left of that point; at 290 yards the boundary of a field passing away to the left at a slight angle to the road, and at 8 yards from the end of the station-line the sides of the road 5 yards on each side of that line. The breadth of the road being only stated at two points on the line, it is to be concluded that it does not vary between them. It is hardly necessary further to explain in detail the plotting of the remainder of this field-book, as the draughtsman will now have no difficulty in prosecuting it by himself.

It must be observed that in plotting the work on paper the interpolations * or other means of fixing the positions, forward-angles, check-bearings, and extreme lengths of each station-line are first laid down in order to form an idea of the accuracy of the work; and the field-book is then gone over again from the beginning for the purpose of tracing out the intermediate distances and off-sets.*

TRIANGULATION.

38.—Object of Triangulation, and use of Pocket-Sextant.

Triangulation is the laying down on paper of the correct relative positions of certain conspicuous stations on a survey, by a series of triangles, for the purpose of forming a skeleton network to brace it together. It prevents any serious error from creeping into the work by having certain fixed points which are constantly checking the different operations.

To attain greater accuracy in laying down the triangles, the pocket-sextant is occasionally employed. It is an instrument by

* See section 45.

which only the angle between two objects and the eye of the observer may be measured, without any reference to the north point. It has the disadvantages of not giving the true horizontal angle but that contained in a plane passing through the three points observed, of not giving angles above 120°, and of requiring the sides of the triangles to be at least half a mile long to compensate for the parallax or unavoidable displacement from position of observation in the construction of the instrument.

(PLATE V.) In making horizontal angles with the pocket-sextant, the lid having been taken off and screwed on to the bottom, the instrument is held in the left hand, when the observer, looking from the hole in the slide K, through the clear part of the horizon glass L, directly at the left-hand object (by screwing round the pinion M), brings the reflected image of the right-hand object from the index-glass N, upon the quicksilvered part of the horizon glass O, till it coincides with the direct image of the position of the left-hand object. The index-arm P on the top, which carries a vernier Q, having revolved with the index-glass over the graduated arc R, the number of degrees and minutes between the objects can now be read off by the aid of the magnifying glass S.

The instrument is also used for taking the heights of objects, when it must be held in the right hand, and the reflection of the upper object brought down to the lower object.

39.—SELECTION OF A BASE.

Triangulation entirely depends on an accurately measured base line.* This base should be measured several times and the mean distance taken between the different results, so as to insure as little error as possible.

In selecting a position for a base, the surveyor must try as far as possible to obtain a long piece of level ground free from obstructions, either along the top of a hill or the bottom of a valley. It must be in an exposed position, with prominent objects at each end, and as near the centre of the proposed sketch as possible.

Durable objects, if accessible, whether natural or artificial,

* See section 45.

should always be preferred; as they serve either to verify or to extend the work, if necessary, on any future occasion.

In small surveys of one or two square miles, the proportion of the length of the base to the extent of the ground should be about one-third of the distance across the country proposed to be taken in. This proportion will decrease as the size of a survey extends, until it reaches a maximum in the trigonometrical survey of a country, that of the Ordnance Survey of England having been about one-sixtieth the breadth of the Island. The ratio between these two extremes gives an increase to the base of about one-twelfth of a mile for every five miles of lateral extent. It is found that one-third will, as a general rule, give a series of well-shaped triangles for field-sketches.

40.—Measurements by Pacing and Chain.

For military purposes it is generally found sufficient to measure distances by pacing.

Since the "scale of shade" has been introduced, the pace of 36 inches, or 1 yard, has been used instead of the military pace of 30 inches, on account of that scale having been constructed for a scale of 6 inches to 1 mile in yards.

The pace of 36 inches is very inconvenient, as in measuring upon slopes or heavy ground, the step has to be made so long as to be seldom accurate, and especially in this case when the surveyor is fatigued towards the end of a day's work. Those who find it troublesome to reach yards in pacing, can bring distances measured in paces to those of yards, by dividing the paces by 6 and subtracting the result from the original number of paces.

(Plate V.) Linear distances are also measured with a tape or Gunter's chain. They are both 66 feet in length, or 80 chains to 1 mile. The latter is divided into 100 large links, joined together by smaller ones. From the centre of one small link to the centre of the next is 7.92 inches. These links are numbered from both ends (where there are iron handles) to the centre, at every ten links, by brass labels with projecting tongues to them; and the centre label at the fiftieth link is generally round. Ten arrows accompany it, to mark the end of each chain as the measurements proceed.

41.—Diagonal Scale.

(Plate V.) It may perhaps be here convenient to explain the construction of a diagonal scale of chains.

Draw the line AB equal to any number of inches on which the scale is proposed to be constructed. AB will represent a mile of 80 chains, or 8000 links. Divide it into 8 parts, each representing 1000 links, and let fall perpendiculars from the points of division. Slide 10 equally distant parallel lines under AB at any distance. Subdivide the left-hand division into 10 equal parts, each of 100 links, and rule the diagonals 100, 200, 300, &c. Number the scale as in the example.

A dotted line has been placed in the diagram, over the distance corresponding with 3475 links; from which example the taking of measurements from the scale will be understood.

It will be noticed that the diagonal scale gives the power of subdividing any line very accurately down to tertiary divisions; so that yards, for instance, may be subdivided down to feet and inches, or hundreds of yards may be read from this scale down to single yards.

In constructing a diagonal scale of hundreds of yards, it will first be found necessary to discover the length of a line corresponding with some convenient number of hundred yards which can be expressed on the paper. This can, of course, be found by simple proportion; as a mile is to the number of hundred yards required to be expressed, so is the length of the supposed scale to the actual length of the line to be represented.

Supposing, for instance, it is required to construct a scale of 24 inches to a mile, but at the same time either no measurement for the drawing is required above a certain length, or the size of the paper would not admit of a greater extent being expressed than that length; then, if this is understood to be, say 400 yards, the proportion will be thus found:—

yards		yards		inches
1760	:	400	::	24
44		10		6
11		6		
		11)60		
		5.45 + inches.		

This will be the line AB in the above example, which will then have to be subdivided. Of course the particular example here taken could be found in a still easier manner, on account of there being scales of 4, 6, and 12 inches on the orometer; from any one of which the length of 400 yards on a 24-inch scale could be found by simple multiplication.

42.—Selection of Points of Triangulation.

The triangles should be well scattered over the surface of the proposed ground, and where no convenient permanent objects exist, the points must be marked by temporary flags or poles.

(Plate V.) The lines to these objects should not intersect at too acute or too obtuse angles to one another like M and N, as in that case the slightest error either in observing or protracting them from K and L, as shown at O and P, will materially affect their proper positions by proportionally making a vastly greater error in the lengths of the sides. Were it possible to get all the angles right angles, not only those with the line from which they are protracted, but also in addition that at the point of intersection, the causes of error would be reduced to a minimum; but as this is impracticable, the nearest to these available is secured; that is, as a general rule, triangles as nearly equilateral as possible should be obtained, which would only give an error of intersection such as the difference between Q and R.

From the impossibility of getting a sufficiently long piece of level ground, in large trigonometrical surveys, for measuring the base upon, this equilateral formation of the triangles cannot at first be obtained. It has been found necessary, in that case, to make the triangles immediately dependent on the base rather longer in their sides than in their bases; and gradually, on these sides, to build up larger triangles as they recede from the original base, until the proper formation has been arrived at. Also in extensive surveys secondary triangles of a smaller size are afterwards constructed within the original triangles, in order to give still more points for checking the work. When great accuracy is desired, the sides of the triangles will require to be calculated trigonometrically; so as to be able to fix the points by means of

the lengths of the sides of the triangles, instead of by the size of angles, which gives a truer result.

(PLATE V.) Having selected a base AB on a suitable part of the ground, let the surveyor take the bearing of it from the point A and then observe the angles to C, D, E, and F. Having carefully measured the base AB as often as he considers necessary, let him from the end B test the bearing of the base back to the point A before taking the angles to G, E, C, and D. The base having been laid down to scale on the paper, and these angles protracted from the ends of it, will so far settle the positions of C, D, and E.

When it is necessary to avoid very acute or obtuse angles, or to decide on the positions of stations not seen from the ends of the base, the sides of triangles already laid down, as AC, or EB, may be used as supplementary bases, to secure the positions of any other points, such as F or G. Consequently, on proceeding to C an angle to F will fix that point, and if G is not yet marked another angle from E will effect that object.

To test the accuracy of the work, check-bearings* as CG and EF should always be taken from one set of points to others which have been settled by triangles independent of them; either right across the sketch as CG, or from one outlying point to another as EF, to the stations already fixed by triangulation.

TRAVERSING.

43.—DEFINITION OF TRAVERSING.

Traversing is taking the bearings and distances along roads and boundaries with some instrument, for the purpose of being able to find out their different bends, with the view of eventually laying down their outlines upon paper.

The station-lines are so selected as to be as long and few as possible, provided they do not entail too long off-sets, so as to economise labour and obviate errors by taking fewer angles. To carry out this principle, it may be laid down as a general rule that no off-set should exceed 50 yards in length. The whole

* See section 45.

ground along the line from one station to another must of course be distinctly accessible as well as visible.

It will be found of the greatest convenience in facilitating the plotting of the work afterwards, if all entries of angles in the field-book are made in red ink, and all distances in black. With a pencil, which is red at one end and black or blue at the other, this can also be done in the field.

By this means the confusion of angles which have to be protracted, with distances which must be measured, is entirely guarded against.

Before carrying out the process of traversing in the field, it would be desirable if Sections 31 to 37 were carefully revised.

44.—Finding the Place by Interpolation.

Interpolation is finding the position of an unknown point, by taking the angles to two known points, and protracting the opposite angles from these points.

(Plate V.) For instance, if E and F are two points already settled on the paper, and it is wished to find a point G not yet known on the paper, let the surveyor go to the point on the ground whose position on the paper he wishes to determine, and finding the angle to E to be 342°, protract that angle to the right instead of (the direction it would naturally fall) to the left of E. In the same way let him find the angle to F to be 67°, and protracting it to the left of F, the two angles will intersect on the paper at the required point; because as the spot is somewhere on both of these lines, it can only be at the point where they meet.

It is preferable to select the known points, so that the intersection of the lines may form nearly a right angle; those stations at the same time being preferred which stand nearest to the surveyor. Although points of triangulation are the best to interpolate from, still any other points already fixed upon the paper may be made use of for that purpose.

45.—Conventional Terms.

"Base:"—An accurately measured line from which triangulation is established.

"BEARING:"—A bearing is the angle to any object with reference to the magnetic meridian.

"BENCH-MARK:"—See Section 72.

"CHECK-BEARING:"—One taken to test the accuracy of triangulation.

"CLOSING:"—Working up to a point already laid down in traversing is called closing upon it.

"CONTOUR:"—See Section 13.

"CREST:"—The crest is the highest part of any upper-feature.

"CROSS-BEARING:"—See Section 101.

"DATUM-LEVEL:"—See Section 18.

"DIRECTING-LINE:"—One of which the bearing is taken from some known point for the purpose of measuring upon it the direct distance to any object.

"FORM-LINE:"—A thin dotted line in the direction of a part of a contour, placed on a hill where any definite shape or change of slope takes place which has not been cut by a contour, to show where the line of shading is to be carried.

"FORWARD ANGLE:"—A forward angle is the one taken to guide the line of pacing from one station to another.

"GRADIENT:"—Any degree of continuous slope.

"INTERPOLATION:"—See Section 44.

"KNOLL:"—A knoll is an under-feature falling on every side.

"LEVELLING:"—The operation by which the difference of vertical elevation between different points on the earth's surface is determined.

"MERIDIAN:"—The arc joining the poles of the earth, through the station of an observer.

"NECK" or "COL:"—The contracted ridge joining two hills of greater height.

"OFF-SET:"—An off-set is a distance measured outwards at right angles to a line of direction.

"ORTHOGONAL:"—An orthogonal line is one taken down a hill at right angles to the contours.

"PLOTTING:"—Plotting is the laying down on paper of the angles and distances which have been observed in the field.

"PROTRACT:"—To mark off an angle upon paper either with reference to the meridional or other line.

"RE-ENTRANT:"—A re-entrant is where the crest-line recedes into the higher ground.

"SALIENT:"—A salient is that part of an upper-feature which projects towards the lower country.

"SCALE:"—See Section 7.

"SECTION:"—See Section 17.

"SPUR:"—A spur is a continuously descending under-feature projecting towards the point of meeting of two water-courses.

"STATION:"—A station is the point from which the forward angle is taken, and is represented by a small circle with a letter or number in it.

"STATION-DISTANCE:"—Measurements entered in the centre column of the field-book which are taken upon the station-lines from each station. The term has a somewhat different meaning in Reconnaissance.—See Sections 102 and 103.

"STATION-LINE:"—The one the surveyor walks along in measuring from one station to another, and from which he takes his angles, distances, and off-sets.

"TRAVERSING:"—See Section 43.

"TRIANGULATION:"—See Section 38.

"UNDER-FEATURE:"—An under-feature is a branch springing from a main hill, and forming itself into any distinct formation of ground of a lower elevation.

"UPPER-FEATURE:"—Is one of greater elevation, from which the lower ones spring in succession.

"WATER-SHED:"—The water-shed is the ridge line of any feature, whence the water would be cast off on each side.

MEASUREMENT OF HEIGHTS AND DISTANCES BY CONSTRUCTION.

46.—EXPLANATION OF PROBLEMS.

The following problems have been selected as the most simple; in addition to which, in order to make them available for those who have not acquired a knowledge of logarithms, they have been so arranged that they may be solved entirely by construction. Those who are conversant with trigonometry may, however, work out the different cases still more accurately.

In Section 9 will be found an explanation of the method of taking angles of elevation with the clinometer scale of the orometer.

In the Problems on Heights, the distance of the eye of the observer from the ground in taking the angles, will have to be added to the distance found by observation.

47.—Height of an Accessible Object on a Horizontal Plane.

(Plate VI.) Let AB be the object whose height is required. From the foot of the object B measure a base in any direction. From D, above C, the other end of this base, take the angle of elevation ADE with the orometer to the top of the object.

Given BC, DC, ADE.
Required AB.

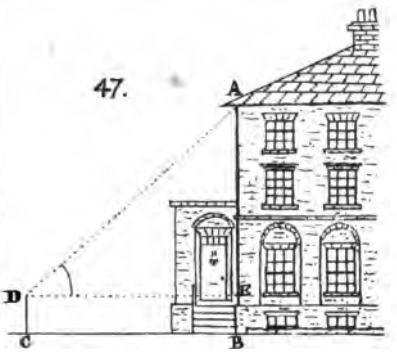
Construction.—Lay down the line BC upon paper from any scale. Draw CD, at the height of the observer's eye, perpendicular to BC; and through D, the line DE parallel to BC. From D protract the observed angle ADE, and from B prolong a perpendicular to BC till it intersects DA in A.

The distance AB measured by the scale will give the height of the object.

(Plate VI.) The height of an object may also be found by another method. Should the sun be shining, let the observer place himself beyond the shadow GH thrown on the ground by the object FG, and setting up a stick vertically, let him measure the height of his stick as IJ, and the lengths JK and GH both of the shadows of the stick and of the object; when by proportion the length of the shadow of the stick will be to the shadow of the building, as the height of the stick is to the height of the building.

Given IJ, JK, GH.
Required FG.

The length of the shadow of the building must be measured in the prolongation of the shadow of the stick.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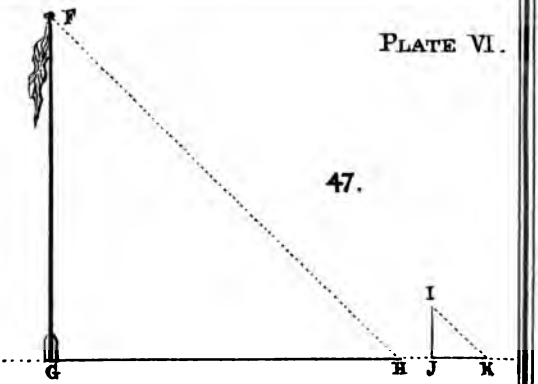
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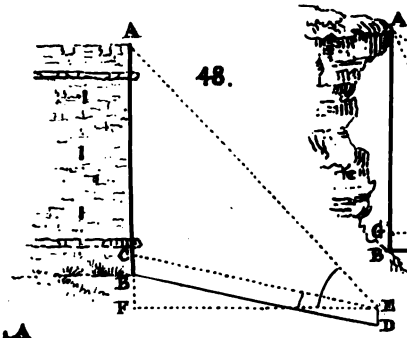
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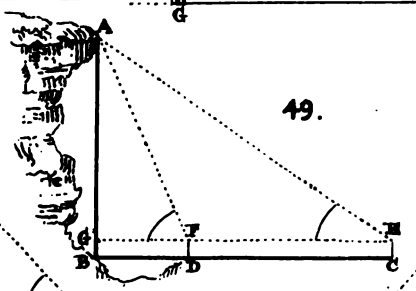
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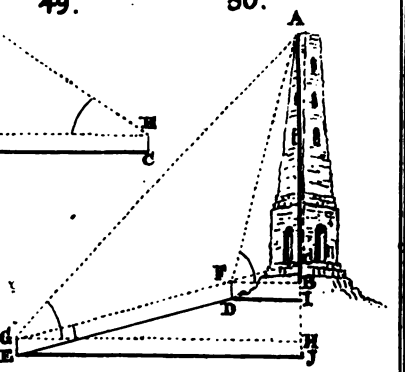
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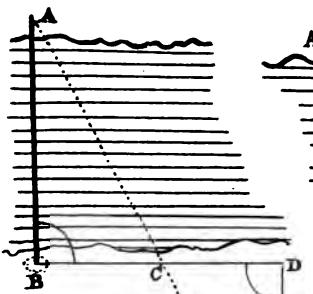
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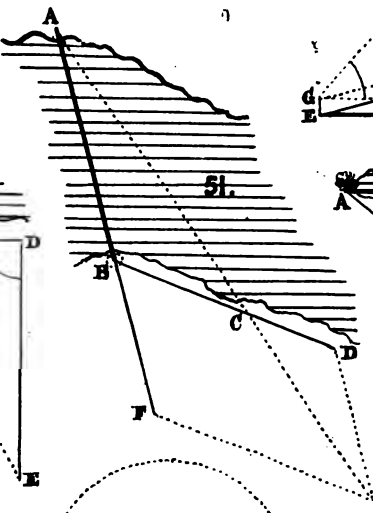
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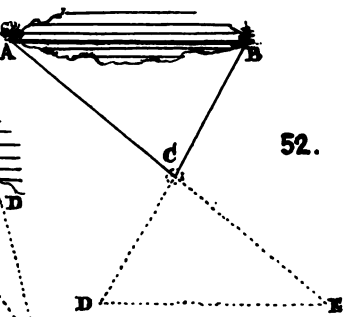
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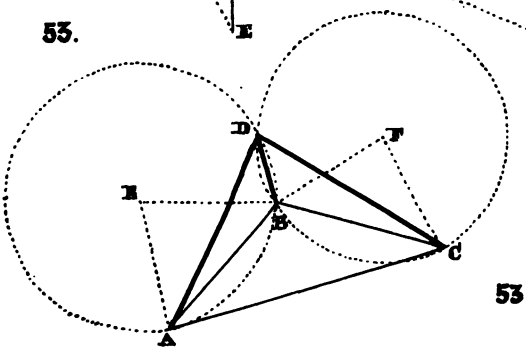
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C
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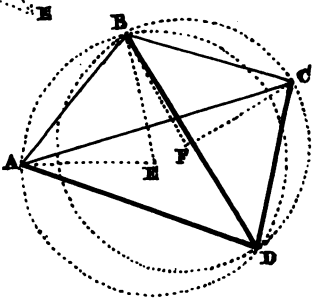

B
C
A
F
E
D
53.

48.—Height of an Accessible Object on Sloping Ground.

(Plate VI.) Place a mark on the building at the height of the eye C, immediately below the required altitude. Measure on the ground from the point B directly below C, a base BD of a suitable length. From E above D observe the angles AEF and CEF.

Given BD, ED, AEF, CEF.
Required AB.

Construction.—Draw a horizontal line FE on paper, and from E protract the observed angles above it. From E drop a perpendicular to EF, giving the height of the eye, and through D draw a parallel to EC. Measure off DB the length of the base, and from B drop a perpendicular to EF and produce it in the opposite direction to A.

The distance AB will be the required height.

49.—Height and Distance of an Inaccessible Object on a Horizontal Plane.

(Plate VI.) Let AB be the height and BC the distance required to be found. Measure the base DC in a direct line from the base of the object, and from above D and C at each extremity, at F and E, observe the angles of elevation AFG and AEG.

Given DC, EC, FD, AFG, AEG.
Required AB, BC.

Construction.—Draw the line DC of the proper length for the base, and GE parallel to it at the proper height of the eye. From the points F and E, found by perpendiculars above D and C, protract the observed angles. From the intersection of the two lines FA and EA at A, drop the perpendicular AB to CD produced to B.

AB and BC can then be measured by scale.

50.—Height and Horizontal Distance of an Inaccessible Object on Sloping Ground.

(Plate VI.) Let AB be the required height and ID, JE, the two distances.

Notice some spot C on the building, at about the height of the eye. Measure the base DE in a direct line on the slope from the object, and from F and G take the angles AFB, AGH, and CGH.

Given DE, FD, CE, AFB, AGH, CGH.
Required AB, ID, JE.

Construction.—Lay down a horizontal line JE with a parallel HG above it, at the height of the eye GE. From the point G protract the angles AGH and CGH. Through the point E draw DE parallel to CG, and on that line mark off the length of the base DE. Through D draw ID, and through F draw BF, both parallel to JE, and protract the observed angle AFB from the point F.

Produce FA and GA till they meet in A, and from the intersection let fall the perpendicular AJ to ID or JE.

AB and ID or JE will then be found.

51.—Distance of an Inaccessible Object from any Given Point.

(Plate VI.) Let A be the object and B the given point. Place a mark on the ground at B, and pace off at right angles to AB, leaving a mark at a convenient distance at C, and again at the same distance at D.

From D, walk at right angles to BD, until a point E is reached in line with the two points, A and C.

Now because CD is equal to CB, therefore DE is equal to AB. The length of DE being measured, will, consequently, give the distance AB.

Given BC, CD, DE.
Required AB.

Construction.—A diagram may be drawn to scale, from the foregoing directions.

Should it be found impracticable to measure BD at right angles to AB, and at the same time inconvenient to take DE as far back as the length of AB :—

(PLATE VI.) Take the point F in the prolongation of AB and D in any direction from B. From D make DE equal to BF, and from F make FE, equal to BD. From E, the intersection of the lines DE and FE, mark a point C in the lines of sight between A and E, and B and D.

Measure BC, CD, and DE, and state as CD is to CB, so is DE to AB, to find the length of the latter.

Given BC, CD, DE.
Required AB.

Construction.—A diagram may be drawn to scale from the foregoing directions.

52.—DISTANCE BETWEEN TWO POINTS WHICH ARE ACCESSIBLE FROM ANOTHER POINT.

(PLATE VI.) Let AB be the required distance. Decide on some point C from which CA and CB can be measured. Prolong the line AC till CE is equal to that length, and produce BC till CD is equal to BC. Measure DE.

Then in the triangles CAB and CED, CE is equal to AC, and CD to CB; therefore DE is equal to AB, the distance required.

Given CA, CB, DE.
Required AB.

Construction.—To draw the diagram, take DE from any scale, and DC, EC, in the compasses, intersecting in C. Produce DC till CB is equal to DC, and EC till CA is equal to EC. Join AB.

53.—POSITION OF AN OBJECT FROM THE OBSERVED ANGLES TO THREE KNOWN STATIONS.

This problem is principally employed in laying down the prominent points in maritime charts, or finding the position of a ship near land, when access cannot be had to an instrument called a station-pointer.

(PLATE VI.) The stations A, B, and C form the points of a triangle, the distances of which from each other are known; and

from a point D the observed angles with A and B, and again with B and C are taken with the pocket-sextant.*

Required to find the position of D and its distance from the given points.

Given AB, BC, AC, ADB, BDC.
Required DA, DB, or DC.

Construction.—Subtract double the angle ADB from 180° and protract half the remainder from each end, and towards the side from which the observations were taken, of the line AB. From the point of intersection of these lines in E, describe the circle ABD.

In the same way subtract double the angle BDC from 180°, and protract half the remainder from B and C, to find F the centre of the circle BCD.

The angle AEB at the centre of the circle, being by construction double the given angle ADB at the circumference, and BFC in like manner double the other given angle BDC, the point D must lie at the intersection of the two circles, and is consequently in the required position with reference to the three given points, and is open to two solutions, according as the station is above or below the given triangle.

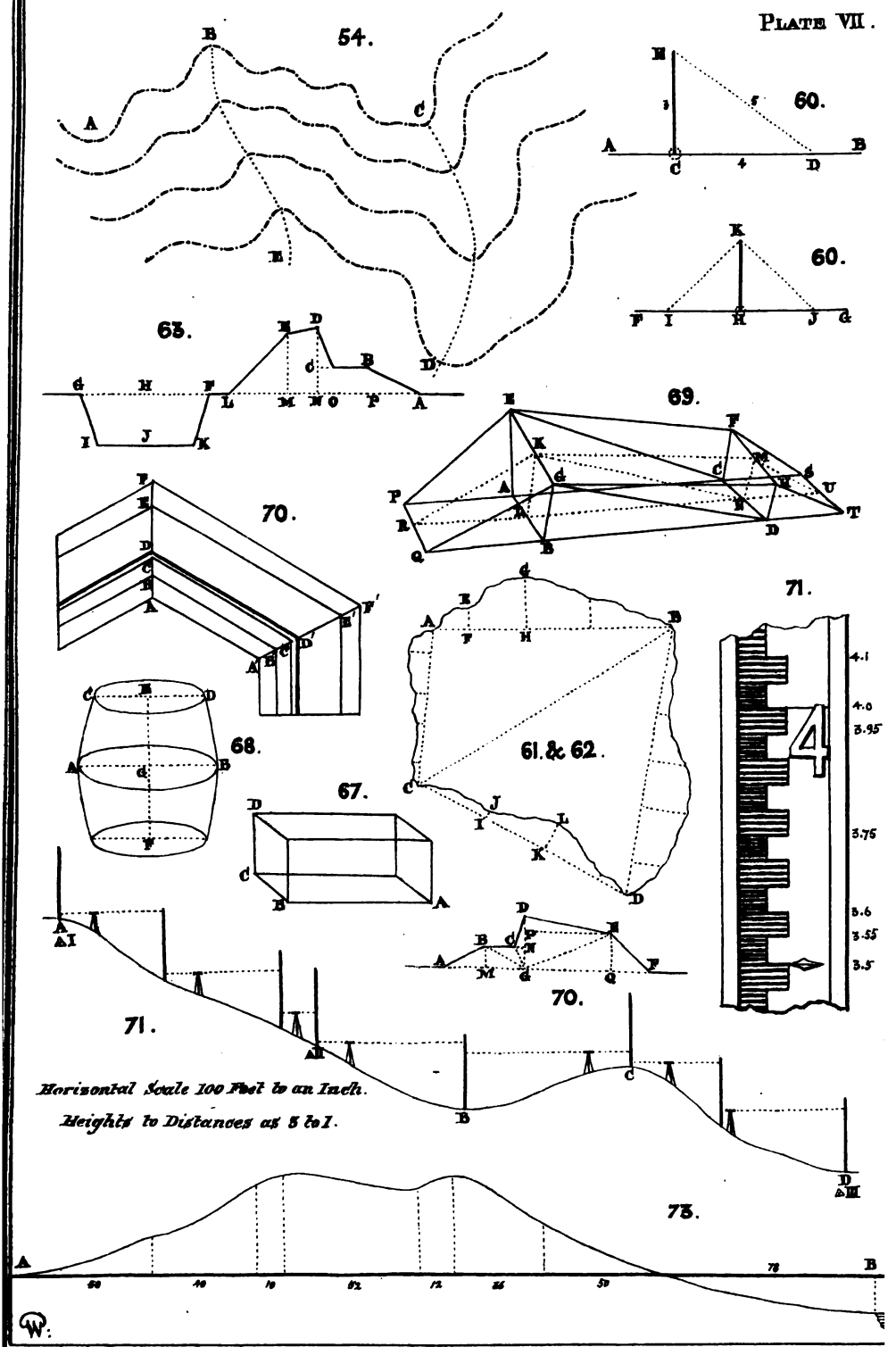
The distances may now be measured by the scale on which the figure was constructed.

There is, under ordinary circumstances, a point both below as well as one above the given triangle from which the same conditions as to angles will hold good. By laying off the angles on the other sides of the lines to that which has first been done, the position of this last point can also be fixed.

If the sum of the two observed angles ADB and BDC exceeds the angle ABC, or should the same angles exceed 180°, there will only be one solution to the problem, as in both these cases the unknown point D can then only lie somewhere below the point B, falling in addition in the last case within the given triangle.

Should either of the given angles exceed 90°, subtract them from 180° and proceed with the remainder as if it was the observed angle, taking care to protract the angles on the

* The method of taking angles with this instrument is described in section 38; but should it not be available, the bearings of the stations can be taken with the prismatic compass, and their differences will give the sextant angles.


54.
60.
60.
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61. & 62.
71.
70.
71.
Horizontal Scale 100 Feet to an Inch.
Heights to Distances as 5 to 1.
73.

opposite side of the line to that which would be done were the actual angle employed.

When the unknown point lies below the base of the triangle, it is possible that it and the three given points may all lie in the circumference of the same circle. In that case the position of the unknown point cannot be determined without the assistance of a compass-bearing to one of the known points.

TRACING CONTOURS WITH THE OROMETER.

54.—Orthogonal Lines of Direction.

(Plate VII.) A normal is a straight line at right angles to a tangent to a curve; but an orthogonal * differs from it in that it may be either straight or curved. In fact, it is made up of a succession of points, which may constantly be changing direction, although, at the same time, necessarily cutting each contour vertically.

The crest * line ABC of the upper-feature having been laid down as will be explained in Section 78, orthogonals, such as CD, are lightly traced in succession with the pencil, by the eye, from each principal salient down the general direction of its water-shed.*

Should it appear vague to beginners to trace these lines from the higher ground merely by the eye, one or more points on each orthogonal may first be found by interpolation * before drawing the line, or if preferred a succession of bearings * may be taken as the work advances, great care being observed to keep the ridge line; but this under ordinary circumstances will not be necessary, as the errors arising from observing and protracting a succession of short bearings will, in all probability, not enable the surveyor to arrive at a truer result than were he merely to check the line occasionally by interpolation on the principal under-features, and to trace in the rest of the line by eye.

The reason for selecting the salients for running down the orthogonals, is because they follow out most distinctly the true conformation of the ground, and at the same time any small

* See section 45.

error in the observation of the slope, which on these lines is generally most abrupt, will give only a slight variation from the true distance of the contours, whereas, if taken down the re-entrants, any error in the slope will be represented by a much larger distance.

These orthogonals will, as a matter of course, always start as normals to the contour from which they have been begun, although they may immediately tend to change direction.

Orthogonals may occasionally also be run down the principal re-entrants, as at BE, when there is any peculiar conformation of the ground, but they are not generally necessary.

A system, accompanied by serious objections, has by some been adopted, that of taking straight lines by compass down the slopes, as would be done in levelling * with the spirit-level, and on them marking off the positions of the different contours. This plan certainly gives the relative heights of any two points with reference to one another; but as the system of true levelling is not completed, in which the horizontal lines are traced joining these points, it does nothing more. In fact, only a succession of lines are laid down, cutting the contours at every conceivable degree of angle, which has to be allowed for in joining the contours, and requires a very experienced surveyor to do with anything like accuracy; whereas, when true orthogonal lines are established, they in themselves mark out the true shape of the hill, and leave nothing more to be done than that of tracing in the contours at right angles to them, by the general conformation of the ground.

Those who adopt this plan have lately shown that they consider the system of true orthogonals the best, by taking their lines of direction as nearly as convenient at right angles to the contours.

55.—Inclination by Clinometer.

After the direction of an orthogonal has been judged, the declination of the slope should be taken down the hill with the clinometer scale of the orometer to the first point where there is any change in the gradation of the slope. If the thumb secures the line of the plummet to the edge of the orometer, as soon as

* See section 45.

the slope has been observed, its intersection with the graduated arc will give the number of degrees to be read off.

In order to bring the upper edge of the orometer into line with the slope, it is necessary either to stand back above it till the prolongation of the surface of the slope strikes the eye, or to lie or kneel down till the eye is on a level with the top of the grass or crop on the ground. If in the last case the eye is still not low enough, some bush or other object must be judged about the height, and the slope taken to it.

56.—Distance from Table of Gradients.

The number of degrees of the slope having been found, a reference must now be made to the table of gradients, which will give, either on a scale of 12 or 6 inches, as the case may require, the number of yards corresponding with the horizontal distance of a $12\frac{1}{2}$ or 25 feet contour.

57.—Measurement by Pacing.

The surveyor must now pace down the slope, keeping exactly along the water-shed line, which he has marked by an orthogonal on his paper, and at every point where he reaches the number of yards observed from his table of gradients he will stop.

58.—Laying down by Scale.

From the required scale on the orometer the number of yards must now be marked off, taking care to follow out any curves that may exist on the orthogonal line. The object of this is to mark the distance along the line which has actually been paced, for the purpose of giving the position of the surveyor at the intersection of a contour.

The successive points should, as soon as they are ascertained, be numbered downwards from the first contour as 1; in order that no mistake may occur in afterwards joining the points to those on the same level.

59.—Joining the Orthogonal Points.

When by the five preceding processes a sufficient number of

points have been secured on the orthogonal lines where the contours cut at the proper vertical interval, the contours may be traced through them by the hand according to the shape of the ground, leaving any superfluous points that may have been ascertained, to be afterwards joined to their proper contours as the work progresses. Further information on this subject will be found in Section 79.

CHAIN SURVEYING.

60.—Division into Geometrical Figures, and Measuring Operations.

Land may be measured with a chain or tape alone, the surface being first divided into a set of imaginary geometrical figures, or if preferred, merely broken up into the one form of triangles.

Beyond the simple act of being able to measure in a straight line, it is only necessary to acquire the method of practically raising on the ground a perpendicular to another line. This may be done by either of the two following simple processes :—

(Plate VII.) For instance, let AB be the line to which a perpendicular is required to be raised from the point C. Fold the chain into lengths in the relative proportion to the numbers 3, 4, and 5. Hold one end of the chain at C, and 40 links from it hold the eightieth link down on the ground at D in the line AB. Now stretch the chain held at the thirtieth link, and it will give the point E, making the line CE at right angles to CD, because the squares of the numbers 30 and 40 are equal to the square of 50.

(Plate VII.) By another plan, along the line FG mark equal distances HI, and HJ, on each side of the point H from which the perpendicular is to be raised; then folding the chain into two equal parts longer than from I to J, let the ends be held down at these points and the middle stretched till it gives the point K. KH will be perpendicular to FG.

Off-sets for short distances are generally taken with a rod 10 links in length, called an off-set staff.

61.—Mensuration Problems.

In the following, which are some of the simplest problems in mensuration, let a, b, d, t, denote the numerical values of the altitude, base, diagonal, and top in the formulæ for computing the different areas.

To find the area of a parallelogram :—Multiply the length by the perpendicular height, and the product gives the area.

$$ab = \text{Parallelogram.}$$

To find the area of a triangle :—Multiply the base by the perpendicular, and half the product will be the area.

$$\frac{ab}{2} = \text{Triangle.}$$

To find the area of a trapezoid :—Multiply half the sum of the two parallel sides by the perpendicular distance between them for the area.

$$\frac{b+t}{2}\,a = \text{Trapezoid.}$$

To find the area of a trapezium :—Multiply the diagonal by half the sum of the two perpendiculars for the area.

$$\frac{a+a'}{2}\,d = \text{Trapezium.}$$

(Plate VII.) To find the area of an irregular field :—Form its area into a triangle, a trapezium as ABDC, or a combination of these figures; take off-sets to the irregularities in the boundary as EF, GH, thereby dividing the surface into triangles as AEF, and trapezoids as EFHG, and calculate as laid down in the previous cases. The sum of these results will give the contents.

62.—Special Directions in Practice.

(Plate VII.) In devising the most suitable figures for laying down the ground, it should be so arranged that the sides of the larger triangles should pass as near as possible to the boundaries, as AB, BD, DC, CA.

Tie-lines are measured across the large triangles, in order to check the accuracy of the work, as from A to D.

In practice perpendiculars are seldom raised on the ground for the larger triangles, but all three sides of the triangles are

measured instead, and the plan plotted from them, from which the perpendiculars are measured for the calculations.

It will be seen from the diagram of the irregular field that the sides of the larger triangles may fall outside of it, as CD, when the contents of the part formed by in-sets, as IJ, KL, will have to be subtracted from the rest.

A field-book may be kept of the measurements, but if only a small surface is to be surveyed, it will be found safer merely to make the necessary entries on a rough diagram, which also has the advantage of omissions becoming at once apparent.

63.—Area of the Section of a Parapet and Ditch.

Perpendiculars may be drawn from the ends of the lines bounding each slope to the line representing the level of the ground; but in practice this may be simplified to a certain extent by taking advantage of the fact of the interior slope always being the same, and therefore if this part of the parapet be once detached from the rest of the profile, the same calculation will always hold good for it, without having to repeat the process in every instance.

(Plate VII.) It is consequently only necessary to prolong by an imaginary line the tread of the banquette till it strikes a perpendicular from the crest to the ground line, and to drop another perpendicular from the exterior crest to the same line. The profile of the work will thus be divided into two triangles and two trapezoids. The ditch will be either a triangle or a trapezoid in itself.

$\frac{1}{2}$ (DC × ON)	=	Interior slope triangle.
$\frac{1}{2}$ (BC + AN) × CN	=	Banquette trapezoid.
$\frac{1}{2}$ (EM + DN) × MN	=	Superior slope trapezoid.
$\frac{1}{2}$ (EM × LM)	=	Exterior slope triangle.
$\frac{1}{2}$ (GF + IK) × HJ	=	Ditch trapezoid.

Example:—

AP = 6 feet	EM = 7 feet
PO = 4 „	ML = 7 „
ON = $1\frac{1}{2}$ „	LF = 2 „
DN = $7\frac{1}{2}$ „	FG = 15 „
CN = 3 „	KI = $11\frac{1}{4}$ „
NM = $3\frac{1}{2}$ „	HJ = 6 „

$$\tfrac{1}{2}(4\tfrac{1}{2} \times 1\tfrac{1}{2}) = \frac{1 \times 9 \times 3}{2 \times 2 \times 2} = \frac{27}{8} = 3\tfrac{3}{8} \text{ square feet.}$$

$$\tfrac{1}{2}(5\tfrac{1}{2} + 11\tfrac{1}{2}) \times 3 = \frac{17 \times 3}{2} = \frac{51}{2} = 25\tfrac{1}{2} \quad \text{"}$$

$$\tfrac{1}{2}(7 + 7\tfrac{1}{2}) \times 3\tfrac{1}{2} = \frac{29 \times 7}{4 \times 2} = \frac{203}{8} = 25\tfrac{3}{8} \quad \text{"}$$

$$\tfrac{1}{2}(7 \times 7) = \frac{49}{2} = \underline{24\tfrac{1}{2}} \quad \text{"}$$

$$\text{Total Parapet} = 78\tfrac{3}{4} \quad \text{"}$$

$$\tfrac{1}{2}(15 + 11\tfrac{1}{4}) \times 6 = \frac{105 \times 6}{8} = \frac{630}{8} = 78\tfrac{3}{4} \quad \text{"}$$

The ditch is made of sufficient size to supply the proper quantity of earth for the construction of the works behind it; and the area of the parapet having been calculated as in the preceding example, the breadth of the ditch may be found by dividing it by the intended depth, which in a field-work varies from 6 feet to 12 feet. This will give the mean breadth if the ditch is of the usual shape, from which the breadth at top and bottom can be found, by adding and subtracting half the sum of the bases of the slopes of the escarp and counterscarp.

For instance, in the case just given, the total earth required for the area of the parapet being $78\frac{3}{4}$ square feet, and the required depth of the ditch 6 feet:—

$$78\tfrac{3}{4} \div 6 = \frac{315}{4} \times \tfrac{1}{6} = \frac{315}{24} = 13\tfrac{1}{8} \text{ feet for the mean breadth.}$$

$$\frac{315}{24} + (3\tfrac{3}{4} \div 2) = \frac{315}{24} + \frac{15}{8} = \frac{315 + 45}{24} = \frac{360}{24} = 15 \text{ feet for top}$$

breadth of ditch.

$$\frac{315}{24} - (3\tfrac{3}{4} \div 2) = \frac{315}{24} - \frac{15}{8} = \frac{315 - 45}{24} = \frac{270}{24} = 11\tfrac{1}{4} \text{ feet for}$$

bottom breadth of ditch.

64.—Calculations in Measuring Land.

The Gunter's chain has already been described in Section 40. There are 10 square chains or 100,000 square links in an acre. If land has been measured with a chain, by cutting off five decimal places from the number of square links, the area will at

once be found in acres; the remaining decimals being then multiplied by 4 and by 40 will bring them to roods and poles.

If the dimensions of an area have been taken in yards, the results will have to be divided by 4840, as there are that number of square yards in an acre.

65.—Marquois Scales.

Great facilities for the construction of geometrical figures are rendered by the use of the Marquois Scales. They consist of two rulers, generally in boxwood, each a foot in length; and a right-angled triangle of which the hypothenuse is made three times as long as the shortest side.

The scales are known by the numbers 20, 30, 60, &c., placed in the middle of each of the two rulers; which figures show the number of parts into which an inch is divided on the inner smaller divisions of each scale. These are merely plain scales of equal parts divided into tens, with the left-hand one subdivided in the usual way into units, and are called the natural scales.

Outside of each natural scale, nearer the edge of the ruler, are divisions numbered from the centre outwards, each of which are three times the size of those on the inner scale. The reason for making them so, is, that as the triangle has by construction the longest side three times the length of its shortest side, so will any distance slid over by the index at the middle of the longest side of the triangle, when applied to one of the scales, be the same as one taken from the natural scale by direct measurement of the shortest side, between the same points, on account of their bearing the same proportion.

These outer divisions are called the artificial scales, and by them the means is obtained of drawing parallel lines, provided the rulers are held sufficiently steadily on the paper, with one-third of the error that would arise in measuring with compasses. In addition to which, perpendiculars may also be raised to any given line with great accuracy by means of the triangle adjusted to one of the rulers.

The artificial scale of 30 gives a plain scale of inches and tenths of inches.

MENSURATION OF SOLIDS.

66.—Necessary Formulæ.

To thoroughly understand the calculation of the cubical contents of solid bodies requires a fair knowledge of mathematics; but at the same time it is possible to give a practical idea of the method of estimating the capacity of one or two of those most likely to be required by officers, as an assistance to such as do not otherwise possess the requisite amount of information on the subject. A selection of these with only the necessary formulæ for the individual cases is here appended.

67.—Cubical Contents of a Rectangular Case.

(Plate VII.) This is technically designated a parallelepiped, and the volume is obtained by multiplying together the numerical values of the length, breadth, and height of the object.

Let AB = The length of the base.
BC = The breadth of the base.
DC = The height.

Then the volume = AB × BC × DC.

Example :—Given the length of a box = 3 feet 6 inches; the breadth = 1 foot 8 inches; and the depth = 1 foot 6 inches. Required the contents.

$$3' \ 6'' \times 1' \ 8'' \times 1' \ 6'' = \text{Contents.}$$
$$42'' \times 20'' \times 18'' = 15120 \text{ cubic inches.}$$

= 8 cubic feet 1296 cubic inches, or $8\frac{3}{4}$ cubic feet.

The baggage of troops, although generally weighed in scales when it is to be conveyed by land, is, for the purpose of saving time, measured externally by the foregoing process when it is to be shipped.

The Government allowance, as laid down in the Queen's Regulations, is at the rate of 5 cubic feet to each cwt., or 100 cubic feet to each ton; no case being larger than $3\frac{1}{2} \times 2 \times 3\frac{1}{4}$ feet, nor heavier than 3 cwt.; but shipping merchants allow 40 cubic feet for heavy goods, and 60 cubic feet for light ones, for each ton in weight. This is rectified according to the average of any parti-

cular cargo, and iron or any others specially heavy, or from their shapes impossible to measure, are always weighed.

About 23 cubic feet of earth make up a ton in weight.

68.—Capacity of a Cask and the Weight of Water Displaced.

(Plate VII.) A cask may be supposed to be formed of two frustums of cones of which the bases are joined at the bung diameter.

Now the formula for finding the volume of a frustum of a cone, is to add the areas of the two ends together, with the mean proportional between them, and to multiply this sum by one-third of the height. Multiplying the square of the radius of a circle by 3.1416 the product expresses the area of the circle, or the ends of the frustum; and a mean proportional between them is obtained by multiplying the two radii by 3.1416. It follows that as the cask is composed of two equal frustums of cones, the same formula will hold good for a cask as for them, only that the height may be taken at once as EF, which is the same as twice EG, when the formula will stand thus :—

$$(ED^2 \times 3.1416) + (GB^2 \times 3.1416) + (ED \times GB \times 3.1416) \times \frac{EF}{3} = \text{Contents.}$$

Example:—The head diameter of a cask = $2\frac{1}{3}$ feet, the bung diameter = 3 feet, and the length = 4 feet. Required the capacity.

The radius of the top will consequently be half of $2\frac{1}{3}$ feet, or $1\frac{1}{6}$ feet, that of the middle being $1\frac{1}{2}$ feet. Substituting these dimensions the formula will be :—

$$\left(\frac{7^2}{6} \times 3.1416\right) + \left(\frac{3^2}{2} \times 3.1416\right) + \left(\frac{7}{6} \times \frac{3}{2} \times 3.1416\right) \times \frac{4}{3} = \text{Contents.}$$

$$\frac{7^2}{6} = \frac{49}{36} \text{ and } \frac{49}{36} \times 3.1416 = 4.2760 \text{ square feet.}$$

$$\frac{3^2}{2} = \frac{9}{4} \text{ and } \frac{9}{4} \times 3.1416 = 7.0686 \quad ,,$$

$$\frac{7}{6} \times \frac{3}{2} \times 3.1416 = \underline{5.4976} \quad ,,$$

$$16.8422$$

$$4$$

$$3 \,\big|\, 67.3688$$

$$22.4563 \text{ cubic feet.}$$

As there are 62.5 lbs. of water in a cubic foot, the cask will hold 1403.5 lbs. The sides of a cask being slightly curved outwards will, however, naturally contain rather more than this quantity.

If the cask were corked and pressed down into water, it would of course displace the same quantity that it would hold, plus the thickness of the material of which it was constructed, which may be left out of account.

Should it be required to find for military bridges or rafts the weight that a cask or other body will bear without sinking, it is only necessary to subtract the weight of the floating body from the weight of the water displaced. The specific gravities of different species of woods from oak to larch vary from 970 to 530 ounces in each cubic foot; so that if the solid contents of a log be obtained by the formula laid down in Section 95 and multiplied by the number of ounces in a cubic foot of the wood, the weight to be subtracted from the cubic foot of water will be obtained. It is, however, usual to allow a margin of about a twelfth for leakage when casks or pontoons are used in addition to the weight of the superstructure, which has to be deducted from the buoyancy.

The weight of fluid in a cask can be found by allowing 10 lbs. for the weight of each gallon of water.

69.—Volume of an Excavation for a Road-Cutting.

(Plate VII.) Let EGBA·FHDC represent the prismoidal solid, and PQ·EABG, ST·FCDH the two triangular prisms or wedges whose content is required.

Make the mid-section KRLNUM in the direction of a plane at right angles to the planes terminating the cutting, and consequently parallel to the sides of the roadway. Join KL, MN, and KN.

Then the plane passing through GKECND will divide the centre excavation into two wedges, the ends being already in the form of wedges, whose volumes being found will give the required result.

Now the formula for finding the volume of a wedge, is to multiply one-third of the sum of the three edges into the area of a section perpendicular to them; and the area of that section being triangular, it will be found by taking half the product of the base and perpendicular, and it is self-evident that NL is the perpendicular height of both the triangles of the mid-section. The length of KL can be found by multiplying EA and GB together and extracting the square root, and MN in like manner from the square root of the product of FC and HD.

The formula will then be:—

$$\left.\begin{array}{ll} \text{The wedge} & EG\cdot FCDH = \dfrac{EG + FH + CD}{3} \times \dfrac{NM \times NL}{2} \\ \text{,,} & CD\cdot EABG = \dfrac{CD + EG + AB}{3} \times \dfrac{KL \times NL}{2} \end{array}\right\} \text{Contents of mid-excavation.}$$

$$\left.\begin{array}{ll} \text{,,} & PQ\cdot EABG = \dfrac{PQ + EG + AB}{3} \times \dfrac{KL \times RL}{2} \\ \text{,,} & ST\cdot FCDH = \dfrac{ST + FH + CD}{3} \times \dfrac{MN \times UN}{2} \end{array}\right\} \text{Contents of end excavations}$$

Example:—

EG = 6 feet	CD = 3 feet	PQ = 3 feet	ST = 3 feet
FH = 4 ,,	EG = 6 ,,	EG = 6 ,,	FH = 4 ,,
CD = 3 ,,	AB = 3 ,,	AB = 3 ,,	CD = 3 ,,
NM = 2 ,,	KL = 8 ,,	KL = 8 ,,	MN = 2 ,,
NL = 18 ,,	NL = 18 ,,	RL = 9 ,,	UN = 6 ,,

$$\text{Or}\left\{\begin{array}{llll} PQ = AB = CD = ST = 3 \text{ feet} & & & RL = 9 \text{ feet} \\ EG = 6 & & KL = 8 \text{ ,,} & LN = 18 \text{ ,,} \\ FH = 4 & & MN = 2 \text{ ,,} & NU = 6 \text{ ,,} \end{array}\right\}$$

Then, substituting the dimensions for the letters in the formula—

$$\frac{6+4+3}{3} \times \frac{2 \times 18}{2} = \frac{13}{3} \times \frac{36}{2} = 117$$

$$\frac{3+6+3}{3} \times \frac{8 \times 18}{2} = \frac{12}{3} \times \frac{144}{2} = 288$$

$$\frac{3+6+3}{3} \times \frac{8 \times 9}{2} = \frac{12}{3} \times \frac{72}{2} = 144$$

$$\frac{3+4+3}{3} \times \frac{2 \times 6}{2} = \frac{10}{3} \times \frac{12}{2} = 20$$

569 cubic feet.

Or $21\frac{2}{27}$ cubic yards.

An embankment is merely a cutting inverted, and can consequently be calculated on a like principle.

70.—Quantity of Earth in a Parapet.

(Plate VII.) Let the upper figure represent the ground-plan of a portion of parapet, and the lower one its profile.

In the lower figure drop a perpendicular from D to G, and join points B, C, and E with G. The parapet will thus be subdivided into as many wedges as there are triangles; and the triangles will be perpendicular sections to the lateral edges of the different wedges. Sufficient data is thus obtained to apply the formula for obtaining the value of each wedge as given in the preceding section.

A formula has been devised from that of the wedge for finding the cubical contents of the earth-work of fortifications, but it seems undesirable to insert it here; because the object should be to make the method of working out these problems as simple as possible, and the calculations in this particular instance are actually more complicated than by reverting entirely to the one formula for finding the volume of a wedge.

Let AA′, BB′, CC′, &c., express the ground lines on the plan; and A, B, C, &c., the angular points in the profile.

The following will be the formula:—

$$\frac{AA' + BB' + DD'}{3} \times \frac{BM \times AG}{2} = \text{Banquette slope wedge.}$$

$$\frac{BB' + CC' + DD'}{3} \times \frac{BM \times BC}{2} = \text{Banquette tread} \quad ,,$$

$$\frac{CC' + 2DD'}{3} \times \frac{CN \times DG}{2} = \text{Interior slope} \quad ,,$$

$$\frac{2DD' + EE'}{3} \times \frac{EP \times DG}{2} = \text{Superior slope} \quad ,,$$

$$\frac{DD' + EE' + FF'}{3} \times \frac{EQ \times GF}{2} = \text{Exterior slope} \quad ,,$$

Example:—The parapet of one face of a hexagonal redoubt with the following dimensions. To find the quantity of earth.

AA′ = 36.5 feet		Height of banquette	3 feet.
BB′ = 43.2 ,,		Breadth ,,	4 ,,
CC′ = 47.75 ,,		Height of parapet	$7\frac{1}{2}$,,
DD′ = 50. ,,		Thickness ,,	12 ,,
EE′ = 63.5 ,,		Slope of banquette in ratio of	$\frac{1}{2}$,,
FF′ = 70. ,,		Interior slope	$\frac{3}{1}$,,
		Superior	$\frac{1}{6}$,,
		Exterior	$\frac{1}{1}$,,

$$\frac{36.5 + 43.2 + 50}{3} \times \frac{3 \times 11.5}{2} = \frac{129.7}{3} \times \frac{34.5}{2} = 745.925$$

$$\frac{43.2 + 47.75 + 50}{3} \times \frac{3 \times 4}{2} = \frac{140.95}{3} \times \frac{12}{2} = 281.9$$

$$\frac{47.75 + (2 \times 50)}{3} \times \frac{1.5 \times 7.5}{2} = \frac{147.75}{3} \times \frac{11.25}{2} = 277.0312$$

$$\frac{(2 \times 50) + 63.5}{3} \times \frac{12 \times 7.5}{2} = \frac{163.5}{3} \times \frac{90}{2} = 2452.5$$

$$\frac{50 + 63.5 + 70}{3} \times \frac{5.5 \times 17.5}{2} = \frac{183.5}{3} \times \frac{96.25}{2} = 2943.6458$$

= 6701.0020 cubic feet, or 248.185259 cubic yards.

The volume of the ditch of a Field-Work can be found by the method for any excavation given in the preceding section.

LEVELLING AND CONTOURING WITH THE SPIRIT-LEVEL AND STAFF.

71.—Explanation of the Principles of Levelling.*

The spirit-level consists of a telescope provided with a spirit-tube of considerable length, under which is a compass box with a magnetised needle. Certain screws exist for adjusting the instrument, and the whole is mounted on a tripod stand.

(Plate VII.) The new levelling-staff is generally 14 feet in length. It is divided from the bottom upwards into feet, tenths, and hundredths. The representation of a part of a staff will be found amongst the diagrams, with figures alongside of it, expressing in feet and decimals of a foot the divisions marked on the face of the instrument.

(Plate VII.) If it is wished to find the relative heights of B, C, and D with reference to A, suppose the diagram to represent a hill in profile. The levelling-staff is erected perpendicularly, facing downwards, on the top of the hill at A; the spirit-level is erected somewhere lower down the hill, so that some number may be observed through the spirit-level on the back-staff; in this case it has been 1.0. The levelling-staff is now removed down the hill beyond the spirit-level, which is turned on its axis, and the forward reading is then taken; here it is 13.2. Subtracting the back-reading 1.0 from the forward-reading 13.2, it gives 12.2 as the level of the bottom of the staff below its former position. The horizontal distance between these points must now be measured with a tape.

The staff is then turned on its base, and the level is removed to some position below it, when the back-reading is taken as before; it is now 1.3, the forward-reading is 10.6, which gives 9.3 as the present level of the staff below its former one. Adding this to 12.2, gives 21 5 for the reduced level of the last point below A; and at the same time it must be remembered to measure the horizontal distance,

* See section 45.

It will be seen that the spirit-level and staff are moved alternately down the hill, and that, when the back-reading is less than the forward one, the process is being carried down hill, whereas when the back-reading is greater than the forward one, it follows that it is being carried up a slope.

Should it be required to establish the positions of 25-feet contours, the following is the process:—The reduced level of the last station was shown to be 21.5, and, having brought the level below the staff, take the back-reading as previously, say at 2.7. Now, as we wish to find a point at 25 feet from the top of the hill, it must be 3.5 (25 – 21.5) lower down, and 3.5 must be added to 2.7 in order to get the proper reading on the forward staff. The assistant must consequently move the staff up or down the slope till the cross-wires of the telescope cut at the height of the number 6.2 on the staff. This fresh point being 3.5 below the second point established, it must be added to 21.5, which will give 25.0, or △ II., as the position of the second contour.

The process is repeated to find such points as B, C, and D, or △ III. Whether in ascending or descending, the smaller reading observed on the staff is always subtracted from the larger one.

72.—Form of Levelling Register.

The observations, which were taken during the course of levelling explained in the preceding section, have been here arranged in the form in which they would be entered in the field.

The point A is assumed to be at some "bench-mark" or established point to which levelling operations have been previously carried. Supposing it was at 267, or at any other number of feet above the level of the sea; then certain corrections would necessarily have to be made in the column of reduced levels.

To test the accuracy of the register, the difference between the sum of the back and the fore-readings, as well as the difference between the rises and falls, should agree with the last reduced level. In this case it is the number 50.

Back.	Fore.	Rise.	Fall.	Reduced Level.	Distance in feet.	Location.	Remarks.
—	—	—	—	0.0	—	△ I.	Station A.
1.0	13.2	—	12.2	- 12.2	59	—	—
1.3	10.6	—	9.3	- 21.5	67	—	—
2.7	6.2	—	3.5	- 25.0	21	△ II.	—
0.4	12.8	—	12.4	- 37.4	85	—	Station B.
9.7	1.9	7.8	—	- 29.6	95½	—	" C.
0.9	13.3	—	12.4	- 42.0	52	—	—
3.8	11.8	—	8.0	- 50.0	72	△ III.	Station D.
19.8	69.8	7.8	57.8		451½		
50.0		50.0					

73.—Construction of a Section from a Levelling Register.

For purposes of instruction it will be found desirable for the student to fill up the accompanying register, which is given in skeleton, by the information derived from the two previous sections.

Back.	Fore.	Rise.	Fall.	Reduced Level.	Distance in feet.	Remarks.
12.0	4.0				50	
	2.5	9.0			40	
10.2		2.3			10	Knoll.
2.1			2.7		52	Neck.
	3.4			+19.0	12	Knoll.
	12.3		9.7		36	
1.4			10.3	— 1.0	50	
	10.6		7.0		78	Level of Water.

If right, he will find the highest hill to be 27.3 above the level of the surface of the water.

(Plate VII.) After the register has been completed, the section from it can be laid down with the greatest facility. Draw a datum-line AB, and on it mark off the lengths, 50, 40, 10, &c., in succession, on any scale from the column of distances. From these points raise or let fall perpendiculars to the extent indicated in the column of reduced levels on some still larger scale as

required by Section 19. Through the extremities of these perpendiculars the sectional line can then be traced.

74.—Running Contours with a Level.

For the sake of continuity in the explanation, it was thought advisable to give in Section 71 the method of establishing, during a series of levelling operations, the positions of 25-feet contours on the surface of a slope. They are marked as △ I., △ II., △ III.

Down certain vertical-intersection lines, taken with the view of showing as much as possible the configuration of the ground, lines of pickets are run at equal vertical intervals. The angles of these lines must be taken, as well as the distances between the pickets.

(Plate VIII.) After several of these points have been thus marked by pickets, the actual tracing of the contours is carried out more expeditiously. A clinometer, or eye-level, is temporarily fixed on a stick at any convenient height, say about 5 feet, and a cross bar is secured across another stick at exactly the same height. The surveyor stands at one of the points, as △ II., with the clinometer, while his assistant moves out on the same level with the cross stick to the next salient F, or re-entrant G; and when, by the instrument, he is found to be exactly on the same level, the angle and distance are taken to him. The surveyor now replaces the assistant, and the work proceeds till they have reached some other, △ II., which had been previously picketed out.

75.—Contouring Register.

(Plate VIII.) A form for keeping a register of contouring is annexed, from which a plan may be constructed. By consulting the diagram, a good idea will be obtained of the principle of carrying out the process.

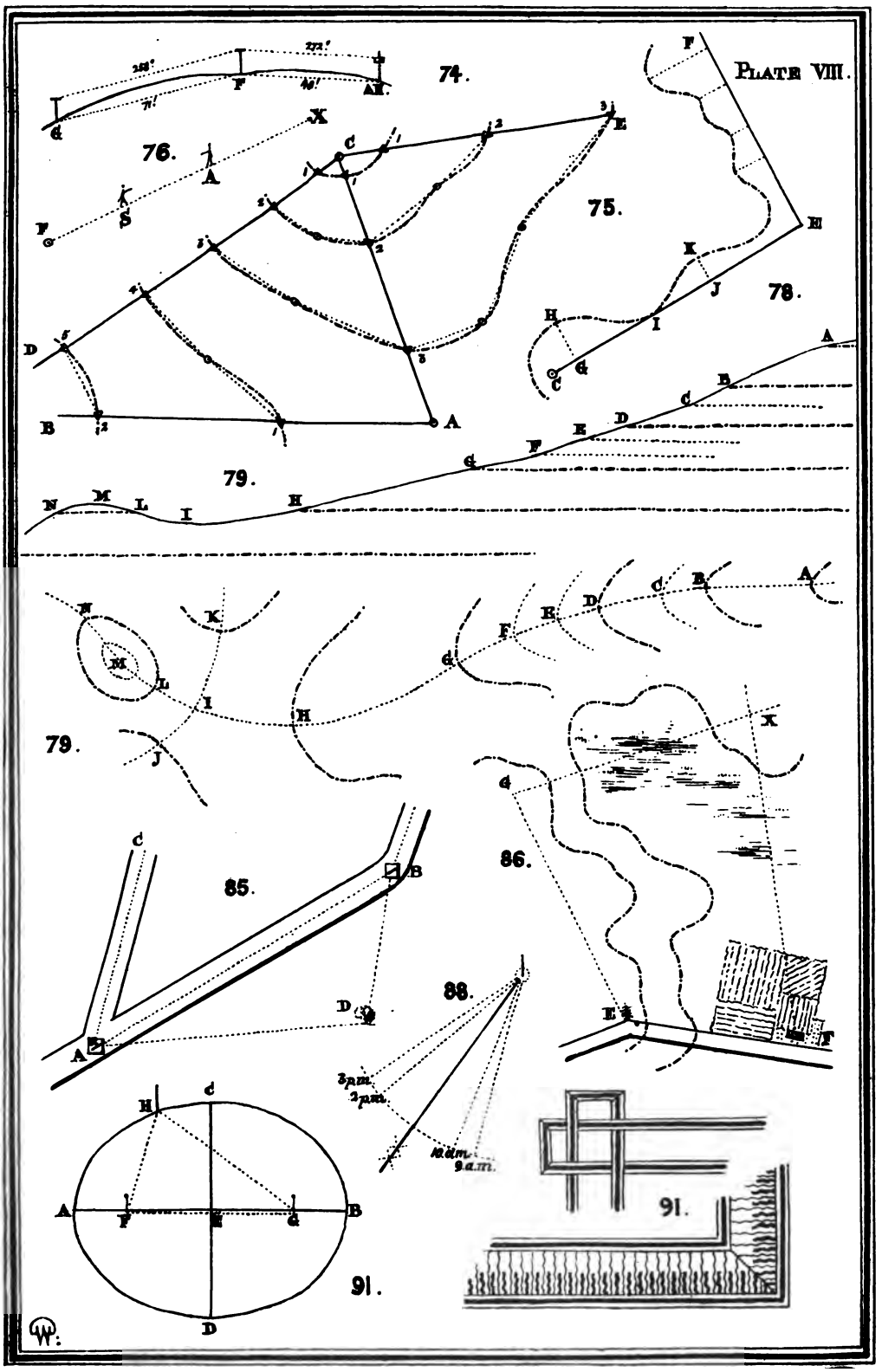


PLATE VIII.
74.
75.
76.
78.
79.
85.
86.
88.
91.
3 p.m.
2 p.m.
10 a.m.
9 a.m.

Station.	Direction.	Angle.	Distance.	Outline.	Level.
		Degrees.	Yards.		Feet.
Bench-mark A	to B 1	272	47½	Concave.	− 5
B 1	,, B 2	,,	57¾	,,	− 10
A	,, C 3	340	26	Convex.	+ 5
C 3	,, C 2	,,	36	,,	+ 10
C 2	,, C 1	,,	22	,,	,,
C 1	,, C	,,	4½	,,	+ 3.2
C	,, D 1	236½	6	,,	− 3.2
D 1	,, D 2	,,	19	,,	− 10
D 2	,, D 3	,,	21½	,,	,,
D 3	,, D 4	,,	26	,,	,,
D 4	,, D 5	,,	32	,,	,,
C	,, E 1	80	12	,,	− 3.2
E 1	,, E 2	,,	34½	,,	− 10
E 2	,, E 3	,,	40	,,	,,
,,	towards C 2	222	24	Convex & Concave.	0
Last	to C 2	233	26	Concave & Convex.	,,
C 2	towards D 2	277	15	Convex.	,,
Last	to D 2	301½	18	,,	,,
E 3	towards C 3	217½	42	Convex & Concave.	,,
Last	,, ,,	203½	35	Concave & Convex.	,,
,,	to C 3	249	25	Convex.	,,
C 3	towards D 3	292	38	,,	,,
Last	to D 3	306	32	,,	,,
B 1	towards D 4	311½	29½	Concave.	,,
Last	to D 4	307	30	Convex.	,,
B 2	,, D 5	312½	25	Straight.	,,

METHOD OF CONDUCTING A SURVEY.

76.—The Triangulation.

With regard to the fixing of horizontal distances, the first principle of every survey is a base line; dependent on which are certain trigonometrical points, whose relative positions have to be carefully laid down.

Under the different headings from Sections 38 to 42 will be found detailed information connected with triangulation, and in the diagram to the last of these sections will be found such a formation of triangles as is suitable for an ordinary field-sketch, and as is likely with a little arrangement to be obtained.

In order to prevent the possibility of confusion, it will be found desirable, in taking the angles from any point, to observe them in their natural order from north, through east, south, and west: the name of the object to which they are directed should

also be written in pencil along each line, as it does not follow that the angles to them from the other points will fall in the same order; and mistakes in the intersections will consequently arise.

It is a good plan to name each point of triangulation after some fact or incident connected with the station, rather than by numbering or lettering them, as "Midrow-Hill," "The Red House," "The Crooked Tree," &c. The possibility of mistaking one point for another is thus avoided.

(PLATE VIII.) Should there at any time be a difficulty in getting up to a point of triangulation for the purpose of taking angles from it, the surveyor S with an assistant A may align themselves between the known point F and the required one X, by "dressing" one another alternately to the right or left till they mutually cover both objects; when the surveyor necessarily being in the exact line between the points, he can take the angle to the point he wishes to settle, and protract it from his fixed point.

After the base and triangulation have been arranged as accurately as possible, they should be put in permanently in red ink; the base line of medium thickness, and the sides of the triangles in thin lines. Check-bearings are also represented in red, by thin dotted lines.

77.—THE TRAVERSING.

The laying down of the roads and boundaries immediately follows the triangulation. Such is the rule at least if there is no actual pressure for time, as it is of importance that the roads should be properly joined and rectified by the triangulation before the hills are commenced.

It is generally begun from some convenient point found by interpolation (as explained in Section 44), or from some actual point of triangulation.

Information on the method of prosecuting it will be found under the Sections from 43 to 45, and a specimen of traversing will be found explained in Section 37.

Where practicable, from the distance being limited, traversing should be closed as often as possible, especially on points of triangulation, in order to test the accuracy of the work.

78.—The Crest-Line.

After a good network of roads and boundaries has been plotted on the sketch, the crest * of the hills may be begun from a point of triangulation or other known point if it happens to stand near the surveyor, or by getting a point by interpolation on one of the principal features of the highest part; and if the summit is small, as on one of the knolls of the hill-sketch given on the lower half of Plate II., measuring off one or two distances from the point found, and by the eye sketching in the first contour of the ground between these points.

(Plate VIII.) If the upper edge of the slope begins to fall from a succession of short curves along a plateau, as between CE, and EF, each set being very much in the same direction, a point may be found at one end by interpolation, or otherwise; from which the angle of an imaginary line being taken to some distant object parallel with the crest of the hills, a succession of off-sets * to where the slope begins will give, in pacing along it, the form of the top of the ridge.

Begin from the point C and take an angle to any object in the direction of E, beyond the head of the first valley. Pace along this line till you reach the point G, opposite the principal salient; pace out (at right angles) to that salient till you reach H. Sketch in the outline at your feet first, and then on both sides of you. Return to the point G, and continue the pacing towards E as far as I; mark in the re-entrant and join it back towards H; continue the pacing towards E till you reach J; pace out to K at the edge of the salient, draw the outline and join it back to I; return to J, and pace up to E, beyond the head of the first valley, to such a position that you can take a fresh line of direction above the crest of the hill, toward the next principal salient at F.

From E take a fresh angle towards F, and repeat the processes of measuring along the line of direction, and taking off-sets, in order to trace in the successive salients and re-entrants up to F.

An irregular boundary, the edge of a lake, or the course of a stream, would be traversed on the same principle as that here

* See section 45.

laid down for working in the crest-line of a hill; the line of direction * being taken to some bush, tuft of grass, or other object which happens to lie in a suitable position; and that line may either be extended by taking up fresh points to pace upon, or altered to another direction as circumstances may require.

79.—The Contouring and Details.

In the Sections on tracing contours with the orometer, it was thought advisable merely to give the general principles on which they are established; but we will now proceed to explain the exceptions which constantly occur in actual work.

It is of course mere chance whether a point representing one of the distances from the table of gradients will fall exactly on the edge of a slope, when a certain complication will arise. How to manage in the difficulty of being required to mark parts of contours on the orthogonals will be best understood by reference to both diagrams simultaneously, the one being in profile and the other a plan of the same ground.

(Plate VIII.) Suppose several parallel lines to be drawn, representing a series of contours cutting a section of a hill in profile, and that from the point A on the crest, the first slope taken down the hill with the orometer is found to be 10°; on consulting the table of gradients, working, for instance, on a scale of 12 inches to one mile, the approximate distance is given as 24 yards. The surveyor will now pace down that distance, and by accident he may find that the slope there, at B, increases in steepness.

Having marked off his 24 yards on the orthogonal line which he had traced on his survey, we will suppose that the fresh slope is found to be 15°, and the corresponding distance 16 yards; but on actually pacing down the slope, it is found that it again changes at C when 8 yards have been measured; so that only half a contour has been reached.

From C the next slope is found to be 8°, for which the distance is 30 yards for a complete contour; but as half a contour has been already measured, it follows that on continuing the pacing

* See section 45.

down the slope, the surveyor must stop at 15 yards, and lay down the point D on his sketch, as the position of the next contour.

The slope still continuing at 8°, the pacing is gone on with; when at 10 yards, the slope changes to 12° at the point E, which gives one-third of a contour; but this last slope is found to extend only for about 7 yards to F, which is also nearly one-third of the next distance of 20 yards. This added to the last measurement gives two-thirds of a contour from D to F.

From F the slope to G is 5°, and it will consequently require 16 yards, or one-third of 48 yards, to fix the position of the next contour at G.

From G to H the distance is supposed to be found to be 40 yards, which will at 6° give an exact contour before any variation in the slope takes place.

At C, and again at E and F, where the parts of contours cut the orthogonal line, dotted "form-lines" * for future use will have to be laid down on the sketch, to show where the changes of slope actually took place.

If from the point H, in coming down a hill, the point I at the centre of a neck is found to be one quarter of a contour below H, and that the ground then rises up a knoll, orthogonals from I will have to be traced down the re-entrants on each side, and the slopes having been taken along each of them, three-quarters of the distances corresponding with these fresh slopes in the table of gradients will give respectively the next lowest contour at J and K. The slope will then have to be taken up towards M, when, on reaching L, one quarter of the distance corresponding with this fresh slope will give the position of a contour on the same level as H.

As the surveyor proceeds with his pacing from L to M, and having marked in the "form-line" * of the knoll, he must be careful to remember what part of a contour he is above the former point; as after he has checked his work by interpolating at M, and started to descend the other side of the knoll, he will have to mark on the fresh slope the point N, at the same part of a contour below M that L was below M. From this it will be seen that orthogonals may be worked as freely up as down a slope.

Contours when finished should be inked in pale colour, with

* See section 45.

chain-dotted or continuous lines, blue if the shading is to bein pencil, and red if in ink, as these colours will show best through each kind of shading.

Such details as were not expressed on the paper whilst the work of traversing was proceeding, are worked in whenever they strike the features of the ground.

80.—The Shading and Finishing.

After the survey has gone through the four stages, and in the order mentioned, it is ready to be shaded in. This may be done either in pencil or ink, but in either case the elementary directions already given must not be deviated from. The scale on which the shading has been established for the English army does not contain sufficient contrast to enable the different degrees of slope to be readily expressed and understood: the steeper slopes should be darker, and those of 2° or 3° be made much lighter.

Although the contours are carried across roads and rivers, shading is not generally taken through them, as it would interfere with their distinctness.

The names of the principal hills, towns, villages, cultivation, and woods should be carefully printed, as well as the directions of the principal roads. Block-printing will be found the best, as being easily and quickly done, and less liable if in pencil to be obliterated. The draughtsman may, however, make use of any kind of printing in which he is most proficient, provided he graduates the size of it according to the importance of the object which he intends to mark.

A scale of miles must be given, subdivided into yards, with a note in printing as to the size of the scale.

A north point must be placed on some convenient corner of the paper, giving the variation of the needle at the time the survey was executed, as well as the true north.

The vertical interval adopted for the contours should be indicated under the scale. It has also been directed that the relative altitudes of the features shall be indicated by coloured numbers, from the highest downwards, but this is of course a work of supererogation where the contours are marked.

It is also desirable to give information as to the nature of the

soil, water, woods, crops, and morasses; but a more extended report comes under the head of reconnaissance of ground with reference to the adaptability of a country for military purposes.

Landscape sketches in spare corners will greatly add to the interest of a survey, if they do not likewise assist in giving an idea of the ground, but care must be taken not to make them too prominent.

FIELD-SKETCHING.

81.—Finding the Position and Uniting Detached Work.

The orometer, or hill-measurer, combines in one instrument several of the principal requisites for field-sketching. It comprises scales of distances, a protractor, a clinometer, a column of horizontal equivalents, a scale of shade, and a table of gradients.

In addition to fixing points by triangulation, there are three ways of finding the position on a sketch, each of which is applied according to the individual case: by "off-set,"* by "interpolation,"* and by "directing-line."*

The system of off-sets is principally used in putting in the crest of upper-features; the system of interpolation applies generally to under-features; the system of directing-line is found convenient when only a short distance requires to be measured on the survey. Any one of the three may be used, but the method applicable to the particular case can alone be acquired by practice in the field.

Should it be proposed to employ several surveyors on contiguous sketches, it will be necessary to unite their work by deciding on such a general system of triangulation as would, besides suiting their several parts, give them individual points common to those working on the different sides of them. This is necessary in order that, when finished, the whole of the separate sheets may accurately join together.

The proposed ground should first be carefully examined, and a hand-sketch made of the apparently best form of triangulation for fixing the most important points. This will naturally have afterwards to be modified to suit different exigences, such as, on

* See section 45.

reaching the points, not being able to see the stations, or on discovering a better form of intersection of the lines.

In addition to the triangulation, the positions where the main roads and rivers pass out of the borders of the sketches after the traversing has been laid down, should be mutually tested and rectified by dotting them off on each sketch, before proceeding further with the work. The different sketches ought even to overlap one another for the facility of gumming them together.

82.—Upper Features and Assimilation of Contours to a Given Datum.

In general the features of the ground are begun by taking the crest-line or top of the highest ground on the sketch; an exception is, however, made when the work is to be fitted on to some previous system of contours on which the level of a particular point has been already ascertained. In this case orthogonals will have to be traced to the first contour, in order to determine its position before beginning the crest. For instance, supposing a "bench-mark"* to be found cut on the base of a monumental pillar showing it to be at a height of 515 feet above the sea, and that a sketch is about to be undertaken of the country surrounding it on a scale of 6 inches to a mile on which contours 25 feet apart are required to correspond with the true heights above the sea. In this case the point to which the survey is to be joined stands at an elevation of 20 contours, with 15 feet over, above the "datum,"*, and consequently the position of a contour 10 feet still higher up the hill must be laid down (if it ascends so far), with others in succession till the crest is attained; but if the object stands on the highest part, then the contour next below the monument will be marked as the first.

In getting the successive points of the first contour as described in Section 78, it will be found better if the surveyor keeps facing outwards towards the lower ground whilst tracing in the general shape, as he will thus be able to form a more just estimate of the formation.

The top of every feature should in every case be marked by a line showing its definite shape. Should this not have been

* See section 45.

obtained by the intersection of an actual contour, then it should be laid down by a single-dotted "form-line" * giving the shape of the ground. This line of shading is not marked in permanently with the contours, but is rubbed out as soon as it has answered its purpose in guiding the shading.

When contours are being traced on two hills standing opposite one another within a reasonable distance, their accuracy may be approximately ascertained by taking the level across the valley. The surveyor, looking along the top of the orometer with the plummet hanging at zero, gets his eye on a level with one contour, then turning round, if necessary, to the other hill, he finds by the orometer where the plane would intersect. Some surveyors attempt to do all their contouring on this principle, but the result can only be a very vague approximation to accuracy, because the length of the instrument is so small in comparison with the distance to the other hill, that it is mere chance if the observation is accurate; for instance, one degree wrong in the verticality of the plummet would give an error of upwards of 5 feet in level at a distance of 100 yards from the observer; besides, the height of no point on the other side of a hill can be ascertained by this process without the help of an assistant. Now the whole object of instruction in this branch should be to enable an officer to make field-sketches entirely independently, which, if this method be adopted, cannot be carried out. In like manner some are satisfied with merely observing how far a slope extends, and always confining themselves to a 6-inch scale; marking off the width apart of the horizontal equivalents from the edge of the orometer; but although this may do on very simple ground, it is perfectly inapplicable on any other.

If not supplied with a table of gradients, the distance which he will have to pace may be worked out at once in the field, by dividing the number of degrees in the angle of the slope into 192, 240, or 480, as the scale may require. The result will give either exactly or very nearly the number of yards required for 10, 12½, and 25-feet contours for scales of 12 and 6 inches to a mile respectively, and by remembering that the number 480 is the initial distance for 25-feet contours, which, as just stated, on being divided by the angle of the slope will result in the

* See section 45.

horizontal distance to be paced; so the distances corresponding with contours at any other interval may be discovered by simple proportion. For instance, if it is required to find the distance for 13-feet contours at a slope of 12° :— $\frac{480}{12} = 40$ and $\begin{array}{ccccc} \text{ft.} & & \text{ft.} & & \text{yds.} \\ 25 & : & 13 & :: & 40 \end{array}$ $\doteq$ nearly 21 yards. If preferred, the calculation may, however, be made by the fractional gradient, as already explained in Section 10.

Should red ink not be accessible, the contours in field-sketches may be indicated by chain-dotted lines, either in coloured or black pencils.

83.—Under-Features.

Under-features are, without exception, joined more or less by the re-entrants to the upper-features, that is, the formation of the upper-feature gradually contracts into a neck, then breadthens, and at last adapts itself to the under-feature, till the slope includes them both. Even if an artificial barrier of earth were thrown across a valley and left to itself, it would soon be washed away by the superincumbent water, leaving one general slope without impediments, gradually getting more gentle at the foot, although very likely frequently bending in its course; but in the case of salients the faces of the slopes form themselves generally into a succession of different breaks more or less steep, even if distinct knolls do not change them into reverse slopes.

The under-features having been formed by the washing away of the soil on each side of them after the water has left the upper-features, it will be understood that the only plan of attaining a true idea of their connection with the higher ground, is by turning in that direction while studying their shapes. It is consequently advisable, whilst joining the contours of the under-features, for the surveyor to face the higher ground, turning his paper at the same time according to the country.

Under-features always spring from salients (occasionally including two or more of them), and never from re-entrants. There are two kinds of them, spurs * and knolls.*

* See section 45.

When a surveyor reaches the end of a spur (where the gentle slope ceases, and the last steep one begins), or arrives at the top of a knoll, he must in every case interpolate, in order to check the accuracy of the orthogonal line which he has traced down to these points, and, if required, make any necessary corrections.

84.—General Instructions.

The decision of the direction in which the work of a sketch is to be carried will naturally settle the position on the paper where it must be commenced.

It will be found a great assistance to the beginner if, in protracting angles in the field, he faces to the north during the operation, and at the same time turns his paper to suit the country, as the angles then falling in their natural relative positions, a source of much error will be entirely avoided.

The line of pacing should always be traced very lightly with the pencil, in order that it may be easily erased. To prevent soiling the paper and confusing the work, it should be rubbed out as soon as no longer required. For the same reason no line of pacing should be drawn down a road in a field-sketch, but the angle having been dotted off, the sides of the road should be drawn in at once at their proper width.

As the surveyor must naturally pace his distances upon the face of each slope, he must acquire the power of so regulating the length according to its steepness, as practically to reduce at once each pace from the oblique measure to its corresponding horizontal one.

From what has been already explained in Sections 54 to 59 and 79, it will be at once apparent that, although it would be necessary to trace orthogonals down all the principal water-sheds, in order to ascertain the position of each individual contour, still the extreme number of contours giving the difference of level between any two points on a sketch whose distance apart is known, can be discovered by merely taking the inclination between them, and dividing the distance as measured on the sketch by the proper number of yards found in the table of gradients. It is desirable to check the number of contours on a sketch by this system, although there is this defect in the plan, that if the points

are very far apart, the slope will be so gentle as to be very difficult to observe with any great degree of accuracy.

Should it simply be required to find the command of one hill over another without reference to contours, multiply the gradient fractionally expressed by the horizontal distance in feet between the hills. For example, with a gradient of $\frac{1}{12}$ and a distance of 2000 yards—

$$\frac{1}{12} \times 6000 = 500 \text{ feet command.}$$

If the gradient is not given it may be discovered by dividing the horizontal distance by the rise. Example :—With a horizontal distance of 700 feet and a rise of 20 feet—

$$700 \div 20 = 35, \text{ giving the gradient as } \frac{1}{35}.$$

SKETCHING WITHOUT INSTRUMENTS.

85.—Adjusting Paper by means of a Ruler on the Back Station.

The art of sketching without instruments has not been prosecuted to the extent which the nature of the subject deserves from its great importance to military officers, who may often be called upon to make surveys without having the means of access to any instruments whatever.

The system as pursued at Sandhurst has been erroneously designated "Eye-sketching," which would imply to those unacquainted with it, a loose irregular style of depicting country, according to its general appearance, from the vague ideas of a sketcher from a distance ; whereas, it is a mathematically accurate application of the old Plane-Table surveying,* although the only implements required are a scale, pencil, and piece of paper.

It depends upon the principle, that with one measured line, the positions of any objects may be ascertained by a practical solution of triangles. This may be easily acquired, and with a little practice can be carried out with surprising accuracy.

(Plate VIII.) A line AB must first be drawn in pencil on the paper, representing a straight part of a road or open ground.

* See section 118.

At one end of this line A, the survey paper is laid on the ground, with the edge of a ruler R coinciding with the line on the paper. The sketching-case with the ruler kept carefully adjusted with the line on the paper should now be moved from one side to the other, till the line lies in the exact direction of the road or object B. Without moving the paper, the ruler is now directed in succession on any object D or direction of road C which may be required, lines being drawn with the pencil along the side of the ruler.

The line of road to B is now measured by pacing, and the distance marked off from the scale along the line on the paper. At this other end of the road B the ruler is adjusted on the paper, to coincide with the line which has just been paced over; the survey being laid on the ground, as in the first instance, and turned round till the surveyor, by looking back along the ruler, gets it to bear on the point A. The object of doing this, is in order to get the sketch in the same relative position to the country as it was in at starting. The ruler being now raised without moving the paper, and directed on the conspicuous object D, which was before visible, will, if a line be traced, give an intersection with the line previously drawn; this intersection will show the proper relative position of D upon the paper.

The eye will perhaps find it an assistance in laying down the direction of a road, or in securing the proper position of the paper by the back-line, to scratch a line on the ground for the required directions, and to adjust the different positions of the ruler by their aid.

The method of tracing the crest of a hill or any other irregular line by off-sets is evidently, of course, equally applicable to this system of surveying as to that where instruments are employed.

86.—Finding the Position of an Unknown Point.

Interpolation in eye-sketching is necessarily carried out slightly differently from the way in which it is done instrumentally.

(Plate VIII.) Lay down the paper on a known point, G, and having adjusted it by some back-station, E, take a line of direction to the required point, X.

Having walked over to X, adjust the paper by the last back-

station G, then laying the ruler on the paper at some other known point, F, let the ruler revolve round that point till it lies in the proper direction for the point where the surveyor is standing on at X. This will necessarily give, by intersection with the line GX, the proper relative position of X on the paper.

It will be seen that the ruler must always revolve on the known point to the unknown one. It turned on G, where the surveyor was standing to find X, whereas it turned in the other case on F, some distance from him when he was at X.

It must be understood that any point already fixed may be taken as the back station on which to direct the ruler for the purpose of adjusting the paper, with the exception of a case of interpolation, when it must be on the last point from which the line of direction was taken.

The general details of the work are laid down by lines of direction and off-sets in the usual manner.

87.—Judging Distances and Slopes.

From the practice which the surveyor will have had in measuring distances whilst working with instruments, he ought by this time to be thoroughly competent to judge pretty accurately any distance up to about 100 yards, beyond which point it will generally be advisable to pace the proper measurement, as the condition of the atmosphere and degree of sunshine will often tend greatly to deceive him. For instance, it should not be thought sufficient merely to look at the shape of the boundaries of a field, and to sketch it on the paper from its general appearance, as the distances will, in all probability, be laid down in an absurdly inaccurate manner; but the actual distances must first be judged to each prominent bend and then laid down from the scale, when the boundary may be traced between the points.

He may now find it convenient, so as to dispense with implements as much as possible, to have the scale of distance on which he is working marked by notches on his pencil. Should he not have access to a regularly constructed scale, any line divided into equal parts either on the sketching-paper or otherwise may form his scale.

He will now also be able to guess the slopes with a good deal of accuracy, and the plan of finding the number of yards corresponding with each, as mentioned in Section 82, may very likely be useful.

If the contours are not required to be shown permanently, the slopes may be taken in profile, and the distance to which each one extends may be judged by the eye. In this case each underfeature would only have its form-lines representing its general shape marked in, as used to be done before contours were introduced. The result may be seen as applied in the diagram to Section 92, in the prosecution of a field-sketch.

The mere command of one spot over another may be found by dividing the distance in feet between any two points, by the denominator of the fraction which represents the gradient between them. Some of these fractional gradients are approximately given in Section 10, and any one can be found by dividing the number 60 by the degrees of slope, for the denominator of the fraction. Take, for example, 250 yards or 750 feet as the distance, and 15° as the slope of which the corresponding ratio is $\frac{1}{4}$: dividing 750 by 4, the result is $187\frac{1}{2}$ feet. From this the number of contours at any given distance apart between the points can be at once determined, if preferred, to the method laid down towards the end of Section 79.

88.—Laying Down a Meridian from Shadows cast by the Sun.

(Plate VIII.) A practical method of laying down a meridian-line* is by erecting vertically a piece of stick on some level surface, exposed to the sun, and by marking the shadow of the stick at two or more pairs of hours equidistant from noon. By taking a mean distance between these observations, on the arc of a circle drawn round the stick, the direction of true north and south may be ascertained near enough for practical purposes, as will be understood from the diagram illustrating the process. The same result may be arrived at by taking one observation of the shadow at noon, but not with the same degree of accuracy.

* See section 45.

The direction of the line may now be transferred from the ground to the eye-sketch in the usual manner.

The meridian-line may also be at once laid down on the sketch, after it has been adjusted to the country when the sun is shining exactly at noon, by holding a pencil or scale upright on any convenient part of the paper and marking by a pencil line the shadow thrown by a vertical edge on to its surface.

MISCELLANEOUS.

89.—Sketching without Contours.

Although for purposes of instruction the theory of showing contours on military plans is decidedly good, still it has the following grave defects. Any process of putting in contours must necessarily be very tedious; the labour being so great, and the result so small, that there will always be the strongest temptation to adapt the contours to the apparent truth; besides when taken with the orometer, an assumption of accuracy is given which does not really exist. Even after they have been inserted, it would only be in very exceptional cases that they would be of any practical use to the general of an army. During a campaign, where sketches have often to be taken under a pressure for time if not in actual presence of an enemy, it would be found impossible to carry out the system, and it does not at all follow that officers who are entirely trained, as at present, to represent ground from actually measured contours, will suddenly be able to represent ground without them.

It would be quite possible, and at the same time of the greatest use, to establish in the army a uniform depth of shade for the representation of slopes, without insisting on contours being shown in addition. All that is necessary is to indicate the formation of the ground and steepness of the slopes by lightly traced approximate lines by the eye, in the general direction of contours, although not continuous, more or less close according to the gradient; and, if necessary, marking on them the degree of the slope intended to be expressed. This is an easy, quick,

and effective way of giving the outline of ground which may afterwards be shaded to the true scale over these imaginary horizontal lines. It has also the enormous advantage of the one scale of shade being able to be applied to every scale of survey, instead of the present restriction to measures and multiples of the 6-inch scale.

(PLATE III.) The diagram to Section 24 illustrating model drawing will show what is intended. By this means it would only be necessary, after the crest had been laid down, to interpolate on all the more important under-features in order to ascertain their true positions, and on each to mark down the proper degrees of slope.

90.—STRETCHING PAPER AND MOUNTING DRAWINGS.

When any elaborate plan has to be prepared, it is better that the drawing-paper should be stretched, both because it is then pleasanter to work upon, and any erasures can be more easily made on the surface.

The paper, of sufficient size, should be thoroughly damped on the wrong side with a wet sponge, and the edges spread with glue or paste to about the breadth of an inch. The wetted side should then be laid on a flat smooth drawing-board, and a clean towel laid on the paper should be smoothed down by the hand from the centre outwards, and the edges of the paper pressed, if necessary, till the paste sticks. The drawing must not be begun till the paper is quite dry, when it ought to be perfectly smooth.

To mount Military Drawings :—Stretch a piece of linen or calico, rather larger than the drawing, on a flat board of still greater dimensions. Tack down the edges of the cloth at every two inches round the margin by small nails, and thoroughly damp the surface with a wet sponge. Now cover the surface with paste well rubbed in.

With a brush spread some thin paste smoothly over the back of the drawing, and whilst an assistant holds it up till only one edge of the pasted side of the paper touches the stretched cloth, pass a wooden roller from the touching edge, which should be next the operator, over the drawing to exclude the air as it is gradually lowered on to the board.

Smooth down the drawing with the hand from the centre outwards with a dry towel spread over the surface, and afterwards form the towel into a soft pad to press the paper all over till it is thoroughly assimilated with the cloth underneath, taking care not to damp or injure the face of the drawing.

Allow the whole to be perfectly dry, which should take place slowly, and cut the drawing off the board with the help of a sharp knife, and a straight edge.

It may seem of very little moment, but it will be found in practice, that unless the paste is stirred only one way round when in course of preparation, it will not stick, and much disappointment will ensue.

Drawings are protected from getting dirty or injured by passing over them one or two coats of fine varnish, after the surface of the paper has been previously prepared to receive it, by a coat of some kind of gum.

91.—Boundaries to Military Drawings.

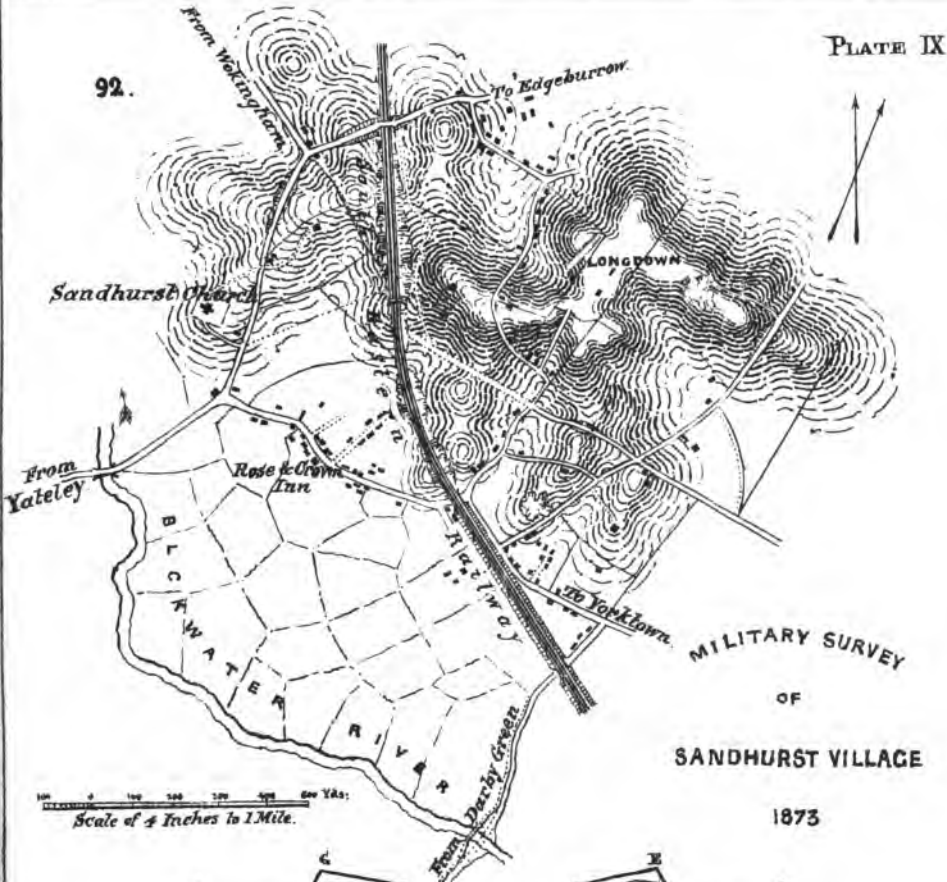
For the purpose of giving a certain finish to military drawings, boundary lines are usually drawn round them at a convenient distance from the margin of the paper. Sometimes they are made perfectly plain, at others, to suit the character of more finished drawings, they are made slightly ornamental.

(Plate VIII.) In the eighth plate two simple though effective kinds have been represented, to suit drawings of a rectangular form. In the case of a drawing being very irregular in shape, it may sometimes be desirable to put in a boundary of the shape of an ellipse.

(Plate VIII.) To trace an ellipse, draw two lines AB and CD, the length and breadth of the proposed figure, and cutting one another at right angles in the centre at E. Suppose that AB is required to be 9 inches long, and CD 7 inches deep; take half of AB or 4½ inches, and, with a pair of compasses, at this distance, draw from C and D the intersections F and G. Set up pins at F and G, and, taking a piece of thread, tie it in a loop, so that when slipped over the pins at these points, a pencil inserted in the bend of the thread may exactly reach C. Stretch the

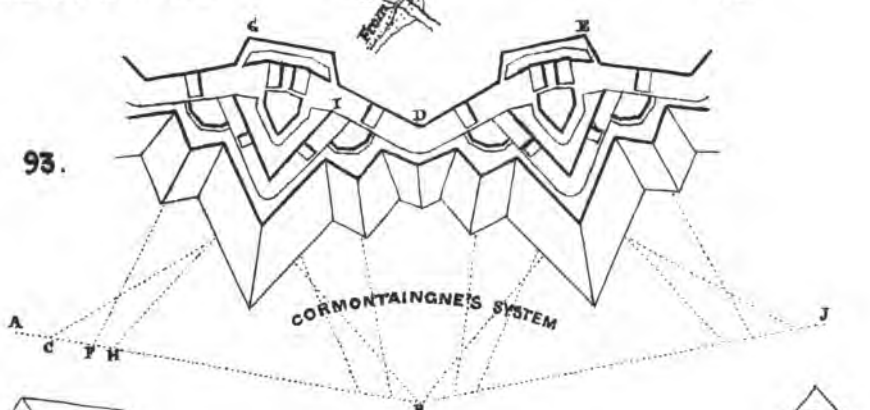
PLATE IX.

92.

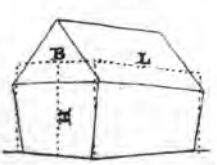


MILITARY SURVEY OF SANDHURST VILLAGE 1873

93.

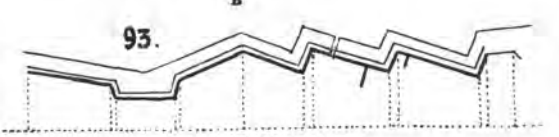


CORMONTAINGNE'S SYSTEM

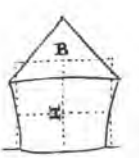


102.

93.



CREMAILLERE-LINES



102.

116.

thread, and by keeping the pencil revolving round the pins, as at H, it will describe an ellipse through the points A, C, B, D.

92.—Recapitulation of the Steps in Prosecuting an Actual Field-Sketch.

(Plate IX.) In order to bring together the detached processes which have up to this time been explained during the prosecution of field-sketching, the copy of a complete survey of about a square mile in extent will be found in the ninth Plate, the following being an explanation of the method by which it should be carried out.

A base is supposed to have been selected from the "Rose and Crown" Inn, Sandhurst village, across the meadows in its rear, in a south-easterly direction, to a prominent tree in a hedgerow; the explanation given in Section 42, of which the diagram is very nearly the triangulation of this sketch, will give the order of and reasons for carrying out this part of the work. Point C being understood as the large house on the western salient of Longdown, D the southern salient, E the bridge, F the church, and G a tree on the bank of the river near the ford.

The roads must then be traversed (Section 43), beginning with the main roads, for instance, at Sandhurst bridge, and working up past the church, stop where the road crosses the railway; then returning to the point where the road leads past the northern end of the base to Yorktown, and having traversed through the village turn down towards Darby Green. The ford at the river being reached, traverse down the right bank of the river (Section 78), when the work ought to close on the bridge. The bye-roads may now be proceeded with in such an order as to obviate the necessity of passing twice over the same ground as much as possible. The railway should be marked wherever it cuts the roads, and its direction occasionally observed with the compass, care being taken not to go too near the iron rails whilst taking the angle, for fear of the magnet being affected by them.

The crest of the hill may be begun by interpolating (Section 44) on the eastern salient of Longdown with two of the points

of triangulation. In this instance, on account of the required point being so much at one corner of the survey, no two points of the triangulation which may be selected for the interpolation will give a really good intersection, the western salient and the eastern end of the base being the two best.

The crest of the hill being very narrow, one northwesterly line of direction taken along the top will be sufficient for getting in the bends on both sides at the same time. This will be changed to the southward when the hill bends, and the work should be closed on the point of triangulation on the southern salient to see that no material error has crept into the work. The remainder of the crest may then be proceeded with, till it again closes on the point on the western salient.

The surveyor now being nearest the northwestern corner of his ground should go down to the successive knolls and ends of spurs in that direction (Section 83), and having settled their positions by interpolation, sketch the general shape of these features and the formation down from the higher ground in each case. The under features to the south of Longdown being so intersected by roads, it will in the case of most of them be found convenient to find their positions by off-set (Section 45) from these roads, and then to sketch in their outlines in the usual manner.

Any details of fields, houses, footpaths, &c., which may have been omitted during the work, must now be laid down on the paper.

The survey is now ready to be shaded in, and the different details clearly and sharply marked. It is usually considered sufficient to shade the highest hill darkest, and the others in succession according to their elevation, well suppressing the under-features; but there is no reason why in this style of field-sketching a scale of shade should not also be employed, as has been fully explained in model-drawing and sketching without contours (Sections 24 and 89).

With the exception of the paragraph about marking the contours, the rest of Section 80 applies equally to this system of surveying, which, however, requires a much more thorough knowledge of the construction of the features of ground (which is best acquired from a long course of model-drawing) than

is necessary where the shading is merely drawn over a set of contours.

In addition to the sketch in Plate IX., a section through this hill is given in Plate XV.

93.—Different Plans for Surveying Fortifications

If a fortification has been constructed on a regular polygon and on any one of the particular systems, a previous knowledge of that subject, leading him to know what to expect in the prolongation and intersection of the different lines, will of course be a great assistance to the surveyor.

(Plate IX.) The following is the ordinary method of surveying a fortified place, such as one on Cormontaingne's system: —Select the morning or evening when the works are most distinctly in light and shade, and proceeding outside the place, from A take the bearing in a convenient direction towards B, and in pacing along the line observe where the prolongation of any of the faces or flanks of the work strike this line. At C take the bearing of CDE:—At F, take FG:—At H take HI. On reaching B change direction towards J, and having taken its bearing, find also the intersection of the successive prolongations whilst pacing along that line. By this means it is not necessary to go near the fortress, but a correct plan can be formed, even if the place were occupied by an adversary, by the intersection of the different angles of the faces of the work.

(Plate IX.) In surveying any simple form of intrenchment, such as Cremaillere-lines, which may be unoccupied, the most convenient method will be found to be that of laying down a long line of direction in rear of the work along its general outline; from which the distance of the crest of the parapet at each salient and re-entrant can be taken by off-set, as given in the second diagram to this Section. The positions of troops can also be ascertained in a similar manner, by taking a long line of direction down the front, and then the depth of each battalion and battery from it by off-set.

94.—Memoranda for Completing a Sketch in a Limited Time.

The following summary of the order of carrying out the work, and distribution of time for a trial sketch, in which the time is limited, will be found useful.

The case given is the Out-of-door Commission examination for Sandhurst cadets, in which the ground covered is rather complicated, and extends to half a mile square. The time allowed is five hours, and the survey has to be completely finished on the ground.

One hour—Base and Triangles.

Extent of ground half a mile square.
Scale 12 inches to a mile.
Survey to be laid down in the centre of the paper.

Base:
- On level ground without obstructions.
- Marked by conspicuous objects.
- In centre of sketch.
- In length from 300 to 400 yards.

Measurements in yards.

Triangles:
- From 5 to 8 in number.
- Well scattered over the surface of the sketch.
- As nearly equilateral as convenient.

To avoid confusion, directions of sides of triangles entered in pencil at once along the lines.

As many bearings as practicable, taken from each end of the base.

Two hours—Crests of Hills.

To be begun at one end, and worked round to the other.

Principal salients and re-entrants taken by the prismatic-compass, but time to be saved as much as possible by measuring on points already settled.

Roads and boundaries to be laid down as they come near the hills, in prosecuting the sketch.

Tracks and footpaths to be omitted.

One hour—Contouring.

Contours at 10 feet apart to be introduced.

Orthogonals run down from the principal salients, beginning to work in succession from one side of the sketch to the other.

Principal points of under-features ascertained by interpolation.

Face the higher ground in joining the contours, bringing them down from the re-entrants to the salients.

Details of houses, woods, and cultivated ground, together with any roads that may cross the under-features.

One hour—Shading and Printing.

Triangulation and contours properly expressed in pencil.

Shading to be drawn by "scale of shade."

The upper features not to be shaded lighter than the scale, nor the upper edge too abrupt.

The under features properly softened off.

Block-printing least liable to rub out.

Scale and north point with memorandum as to width apart of contours.

Name of the ground, and names of the places to which the principal roads lead.

95.—Useful Measures, Weights, and Formulæ.

Many of the following will be found particularly useful, either in surveying or reconnaissance, and military officers will most likely have a necessity for a knowledge of the whole of them at some time or other.

Military pace . . .	=	30 inches.
Yards	=	36 „
French metre . . .	=	39.37 „
Hand	=	4 „
Fathom	=	6 feet.
Chain	=	66 „
Cable's length . . .	=	240 yards.

Mile	=	1760 yards.
Rod	=	5½ „
Horse's stride in walking .	=	about 1 „
Do. galloping .	=	„ 2½ „
2112 Military paces . .	=	1 mile.
Degree of latitude . .	=	69.08 „

Acre	=	4840 square yards. 10 square chains. 100,000 „ links.
Square mile . .	=	640 acres.

Imperial gallon .	=	277.274 cubic inches.
Ton of shipping .	=	40 cubic feet of heavy goods. 60 „ light „

Gallon . .	=	4 quarts or 8 pints.
French litre .	=	1.76 pints.

French gramme .	=	15.43 grains.
lb. Troy . .	=	5760 „
„ Avoirdupois .	=	7000 „
144 lbs. Avoirdupois	=	175 lbs. troy.
Cubic foot of water	=	1000 oz. or 62½ lbs.
Fluid pint .	=	20 „
Stone . .	=	14 lbs.
Gallon of water .	=	10 „
Load of old hay .	=	36 trusses each of 56 lbs.
„ New „ .	=	„ „ 60 „
„ Straw .	=	„ „ 36 „
Cubic foot of brickwork	=	1 cwt.
One rod of brickwork, 1½ brick thick	=	30¼ square yards.
Mean diameter of the earth	=	7916 miles.

French metre is the ten millioneth part of the distance from the equator to the pole.

A unit of work is 1 lb. in weight raised through 1 foot of space.

The average strength of a man is to raise 100 lbs. in weight through 1 foot of space in 1 second of time.

A horse power is 33,000 units of work per minute.

The duty of an engine is estimated by the number of units of work performed in the consumption of 1 bushel of coal.

Pure gold has 24 carats in a lb., each carat containing 240 grains.

Standard gold contains	22 carats of pure gold. 2 „ alloy.
Jeweller's gold contains	18 carats of pure gold. 6 „ alloy.
Standard silver contains	37 parts pure silver. 3 „ copper.
Bronze coinage contains	95 parts copper. 4 „ tin. 1 „ zinc.
Gun metal is composed of	100 parts copper. 8 „ tin.
Gunpowder „	75 parts saltpetre. 15 „ charcoal. 10 „ sulphur.

The circle is divided into 360 degrees.

The circumference of a circle is 3.1416 times the diameter.

Sound travels about 1140 feet in a second, which is at the rate of nearly 5 seconds between the flash and the report of a gun, for each mile.

A pendulum 39.13929 inches in length oscillates once in each second in the latitude of London at the level of the sea.

To find the height of a precipice by the time a stone takes in reaching the bottom. Multiply the square of the number of seconds by 16, for the number of feet.

To find the solid contents of wood in a tree. Multiply the square of a quarter of the mean girth by the length. Example: —Required the contents of a tree with a circumference of 5.2 feet and a length of 17 feet—

$$\frac{5.2}{4} = 1.3 \text{ and } 1.3^2 = 4.29 \qquad 4.29 \times 17 - 72.93 \text{ feet.}$$

These constantly vary according to the rate of exchange.

		s.	d.
Value of	French franc	0	9½
„	German florin	1	8
„	„ thaler	2	11
„	Italian lira	0	9½
„	Russian rouble	3	2
„	American dollar	4	2
„	British colonial dollar	4	2
„	Indian rupee	2	0

RECONNAISSANCE.*

COMPRISING ROADS, RIVERS, OUTPOSTS, AND POSITIONS.

GENERAL DIRECTIONS.

96.—Object of Topographical Reconnaissance.

Before troops move in any direction through a country, it is necessary that the General commanding should have accurate plans of the ground, together with reports on its capabilities for military movements. This information is obtained for him by the officers of the Quartermaster-General's Staff.

In making a reconnaissance of whatever kind, the object is to obtain the greatest amount of accurate military information in the shortest possible time, for the purpose of being compiled into a Sketch and Report for the Officer commanding. Time is, as a general rule, supposed to be limited, even if the difficulty is not still further increased by the actual presence of an enemy; everything must consequently depend on good training aud quickness of eye.

It is of the utmost importance that an Officer, before proceeding to make any description of topographical report, should have clearly defined in his own mind the different objects to which he is particularly required to direct his attention.

97.—Instructions as to Carrying out Reconnaissances.

A General, in issuing the order for a reconnaissance, will always give the extent of country to be embraced, the time allowed for making it, together with any special instructions as to its object.

* "Special Instructions for the Officers of the Quartermaster-General's Department," "A Treatise on Military Reconnaissance," by General W. C. E. Napier, "The Soldier's Pocket-Book for Field Service," by Lieut.-General Sir Garnet Wolseley, G.C.B., G.C.M.G., "The Operations of War," by Major-General Sir E. B. Hamley, K.C.M.G., C.B., &c.

The amount of time allowed is of material consequence, as on it depends the decision of the extent of minutiæ which can be entered into whilst completing the whole report and at the same time carrying out the special instructions. It will also naturally be materially affected by the capabilities of the operator.

In order to exonerate himself from all blame as to the result of the reconnaissance, as circumstances may have materially changed during its execution, of which we have lately had a most striking instance, it is necessary that the Officer appointed to carry it out should provide himself, if possible, with the original of this order, and should in all cases at least prefix a copy of it to his report.

98.—Divisions of the Subject.

A reconnaissance consists of two distinct parts, comprising a sketch of the military features of a certain tract of country, with the position, strength, and distribution of any enemy clearly marked upon it; and a written report, tabulated and arranged according to the class of reconnaissance which is being prosecuted.

The sketch should, as far as possible, contain all the information which can be expressed by military drawing, leaving for the report only those points which cannot be there delineated; as it is quicker for the Officer for whom it is prepared to acquire his information at a glance from the drawing than from reading the report.

By colouring the roads on the sketch with a tint of light brown, according to their relative importance, facility of following them out in the field may sometimes be increased; as although the widths of their enclosures may be accurately laid down to scale, still this may not be a true criterion as to their accessibility.

If the time permits, it is preferable that the sketch of the ground should first be completed, and then written memoranda made with reference to its whole extent, including any special calculations necessary for different requisites. From these memoranda the report will be afterwards drawn out.

In reporting on ground it must be clearly understood that the descriptions only relate to actual objects which are illustrated by the sketch, and with reference to their aspects and conditions at the time of making the report, and not to a possible variation of circumstances which may probably exist at a future time.

April 1873.

General Observations.

Bridges.	Fords.	Bridges.
1	1	1
1	1	1
1	1	1

99.—Means of Obtaining Information

The various subjects on which particular and minute information must be obtained for each kind of report have been arranged and classified under their proper headings, to which have been added instructions as to filling them up.

In addition to that which has been acquired from personal observation, spies, deserters, prisoners, and the inhabitants of a country may be interrogated as to the strength and position of an enemy, intrenchments in process of construction, and roads under repair; also the localities where supplies have been ordered to be collected, with their quantities, and the positions to which their hospitals have been removed; but all such information must be acted on with the greatest caution, as it may be entirely erroneous; and the fact of its having been so acquired must be distinctly stated.

More detailed reports on any special information must also be prepared in a separate form.

RECONNAISSANCE OF ROADS.

100.—Object of Road Reports.

Reconnaissances of roads are made by Officers who generally precede the troops by at least a day's march; in an enemy's country they are accompanied by an escort of cavalry, partly for the purpose of being employed to acquire information and partly for protection.

The object of the Officer appointed to the duty is to produce a sketch of each route by which the different columns of the army are to move, together with the acquisition of information for a report on the general nature of the country, with the obstructions and difficulties to be met with. He has also to collect information as to accommodation, supplies, transport, and water on the line of march.

101.—The Sketch.

(Plate X.) The sketch should be accurate, with such amount of detail as is compatible with the time at disposal for making it.

It should at all events embrace the road and the country immediately adjacent. It is sufficient to put in by eye the general direction of the boundaries of the fields and small roads. The scale may be on one, two, or three inches to a mile.

The sketch should be placed at the left-hand margin, beginning at the bottom of the paper, and ending towards the top without reference to the north. Even if there is not time to survey the intermediate space, still all commanding ground within cannon shot should be found by cross-bearings, and laid down on the sketch.

These cross-bearings are angles taken from two or more points whose positions have been previously laid down on the sketch, without leaving these points, so as to fix by their intersection the position of some other point. It is done on the principle of triangulation, and generally from a road which is being traversed.

102.—The Tabular Form.

(Plate X.) *Form.*—The form itself will be found in the tenth Plate, and is that lately issued in the Army Circulars for 1874—Clause 165—Paragraph 5—W.O. Form 33:—Some slight alterations have been made in it which are not improvements; but it is absolutely necessary that one uniform plan should be adopted for the whole army, and it has therefore been here inserted.

Numbers.—The reference numbers apply both to the sketch and to the report. They are placed at each station of importance, including one at each end of the report. They are arranged from the bottom upwards.

Localities.—In the column of localities are entered the names of places on the road, as well as those near it on both sides. It also includes where the road communicates with important places at some distance.

Distances.—The distances are entered in miles and furlongs, and also in the measures of the country, to all points mentioned in the previous column. The intermediate distances are only stated between each two points on the direct route, but the total distances are always given whether the station is on the road or off it; and are measured in every instance from the point of departure by the nearest practicable route. If accurate, the sum of the intermediate

distances to each point will give the total. The time of marching in each case is taken from the point of departure; the average on a good road being three miles an hour, but this will rapidly decrease as the size of the body of the troops increases. In the form lately published by authority the column for distances in hours has been omitted.

Population.—To find the accommodation, the houses must of course be counted. The permanent inhabitants will average five people to each small house and ten to each larger one; but this, and all other formulæ for making calculations for the reports, will of course have to be modified according to the particular circumstances of the country which is being reconnoitred. Special inquiries will have to be made as to those erected for any particular purpose.

Accommodation.—For temporary quarters for men on a march, a room is considered habitable when it contains a fireplace, and only these are taken into account in making calculations as to space. A square yard of flooring is allowed to each man, not including recesses and passages, the calculations being made for the whole force, although one-third of the men will generally be on duty. Half the house is always left for the use of the inhabitants, except in the case of churches and public buildings, which are generally reserved as hospitals, depôts for stores, or to be fortified.

By taking six times the number of chimney-flues as seen from the outside of a house, the accommodation for troops occupying half the house will be approximately discovered; but the simpler method is usually adopted of allowing twenty-five men for each small house, and from one hundred to two hundred for each larger one. For large buildings it is more accurate to take a quarter the number of square yards covered by the ground plan multiplied by the number of storeys, for the number of men for whom there is space.

The space required for a horse's stall is six feet by nine feet. To find the accommodation, take half the number of yards in the length of an outhouse for the number of horses; and if the breadth is eight yards or upwards, allow for two rows of stalls. An average number of two horses may be attached to each small house, and from ten to twenty to each larger one.

Permanent quarters are calculated at double to four times the space allotted to temporary quarters.

Supplies.—The number of bakeries, butchers' shops, forges, and cornmills must be registered, where the supplies can be utilised for the use of the troops.

Resources in provisions must be discovered, including oxen, sheep, pigs, and goats.

Remark must be made on any special kind of agriculture in the district, with the number of acres of the different kinds of grain; a note being made of *g* for grass, *f* for fallow, *w* for wheat, &c., at the time of making the sketch in the field, in order that the different species of cultivation may be afterwards properly depicted on the finished drawing. The fields may be measured from the sketch at 4840 square yards to the acre, or nearly 70 yards each way.

For the calculation of the contents of hay stacks, allow 200 pounds per cubic yard:* for straw 140 pounds. To find the quantity in a stack (see Plate IX.), take the height from the ground to the eaves added to one-third of the roof (H); multiplied by the mean breadth half way up (B); multiplied by the mean length (L), which in a square or round stack will be the same as the breadth: this gives the cubical contents in yards. Then multiply this result by 200 to bring to pounds of hay, and divide by 28, 4, and 20 to reduce to tons. This is the same as multiplying by 5 and dividing by 56, or very nearly that of simply dividing by 11 for the number of tons of hay in a stack. For a like reason divide by 16 for the number of tons in a stack of straw.

The formulæ will then stand as—

HBL in yards ÷ 11 for Hay.
HBL in yards ÷ 16 for Straw.

Example:—How many tons of hay are contained in a sack 6 yards broad and 10 long, with a height from the ground of 3 yards to the eaves and $5\frac{2}{3}$ to the ridge?

$$\frac{3 + (2\frac{2}{3} \div 3) \times 6 \times 10}{11} =$$

$$\frac{35 \times 6 \times 10}{9 \times 11} = 21\frac{7}{33} \text{ Tons.}$$

Transport.—Under transport give a description of the vehicles of the country. English four-wheeled farm waggons, drawn by

* This is for old hay, new hay will be somewhat lighter.

three horses, carry two-and-a-half tons, two-wheeled country carts with one horse carry a ton. The number and size of boats, and the number of horses, mules, oxen, waggons, carts, and labourers to be obtained must be stated. Under the assumption that 1 of every 5 of the population is an able-bodied man, and that half of these are labourers, it may be taken that $\frac{1}{10}$ of the population will give not far from a true idea of the number of men who would be available for employment by the troops. A report must be made of the access to railways, with their construction, capabilities, and amount of rolling stock.

Water.—The supply of water must be calculated in the streams and wells, and its quality tested. For the calculation for quantity, multiply the average, breadth, depth, and velocity of current to obtain the number of cubic feet per minute. Again, multiply this by 1000 to bring it to ounces; divide by 16 to bring it to pounds; and then by 10 to reduce it to gallons. This result multiplied by 60 and 24 will give the supply passing any given point for each day.

The velocity is found by floating a cork down the stream, and measuring the distance for one minute, which volume of water may then be considered as stationary along that distance. 10 gallons are required for each man or horse, so that if the calculation is worked out it will be found that the breadth, depth, and velocity in feet for one minute, multiplied by 900, will give the numbers for whom there is a supply of water. This admits of leaving a margin for droughts or other accidental failure of supply.

The formula may, by employing the initial letters only to express the whole words, be reduced to—

$$B \times D \times V \text{ (for 1 minute) in feet} \times 900 = M.$$

Example:—A streamlet of drinking water runs at the rate of 50 feet in a minute, and is 1 foot 6 inches in breadth, and 2 inches in mean depth, how many men would it supply?

$$1\tfrac{1}{2} \times \tfrac{2}{12} \times 50 \times 900 = M.$$

$$\text{or } \frac{3 \times 2 \times 50 \times 900}{2 \times 12} = 11{,}250 \text{ Men.}$$

The wells of a town or village may be assumed, unless evidence is obtained to the contrary, to supply sufficient water for the number of men for whom the accommodation has been calculated.

The separate headings of each kind under supply, transport, and water should be grouped together and arranged for each station.

*Nature.**—State the general nature of the road, whether good, bad, or indifferent, the objects on each side being always described as north, east, &c., of the road. In the case of rivers they are stated as being on the right or left bank.

Widths.—The average width of both the main and cross-roads must be measured, and noted if they are inclosed by walls or hedges, contracted, or have any unsafe form of cross-section on the hill sides. The axletree of a gun carriage is six and a quarter feet in length, which must be the minimum width for an emergency.

Construction.—Whether regularly made or only formed by the traffic upon them, also whether macadamised.

Variations.—The variations occurring between any particular points different from the general character; the causes of these variations, and if rugged or stony.

Practicability.—The practicability for infantry, cavalry, and artillery; also for carriages of the country.

Imperfections.—Whether liable to injury in bad weather; any parts really very bad, or any short turns, narrow parts, or other difficulties.

Repairs.—Whether easily repairable and what materials are requisite; if materials can be obtained in the neighbourhood, and in sufficient quantities.

Gradients.—60° inaccessible for infantry, 45° difficult for infantry, 30° inaccessible for cavalry, 15° inaccessible for artillery, and 5° accessible for carriages.

Deviations.—The deviations to be effected on narrow and embarrassed parts, the means of avoiding them, and any proposed new routes for short distances; if the general direction can be improved by adopting a new line, and what work will be necessary in each case.

Obstructions.—The possibility of obstructing or breaking up the road, so as to prevent its being used by an enemy; the means of effecting these objects; and the labour and time necessary for the work.

* The remainder of the paragraphs of this section come under the column of "General Observations," which should be arranged from the top downwards, but each be prefixed by the proper number referring to the several stations.

Buildings.—The materials of which the houses are constructed should be noted, and the apparent strength of the walls.

Bridges.—The construction, stability, dimensions, and defensibility of the bridges; with the means of repairing and destroying them, and the places and materials for constructing new ones.

Fords.—The depth, breadth, nature of bottom, and rapidity of current of the fords: their direction across the stream, and if always passable. The maximum depth for infantry is 3 feet, for cavalry 4 feet, and for artillery $2\frac{1}{2}$ feet.

Ferries.—The number and size of boats at the ferries; the time occupied in crossing; and the means of landing on each side.

Soil.—Whether rocky, gravelly, sandy, clayey, or earthy; and if liable to be cut up by the passage of troops across country.

Rivers.—The breadth, depth, current, channels, banks, navigation, and surrounding country of the rivers must be reported on.

Woods.—There must be given the kinds of trees on each side of the road, their widths apart, and penetrability for different arms; also, if they are intersected by paths and tracks, or if favourable for ambuscades.

Marshes.—The marshes must be examined on the line of route, and how the road has been carried over them.

Defiles.—Attention must be paid to the widths and lengths of defiles, the time occupied in passing through them, whether they can be widened or the obstacles removed which confine them, and the height of the banks on each side, with the power that exists of occupying them.

Specialities.—Under specialities may be noted any peculiar and essential particulars which may not have been included in the foregoing headings; such as the towns if fortified, good military positions and encamping grounds on the line of route, as well as the points where the column of march is likely to be opposed by an enemy.

Conspicuous objects should be noted as they may be turned into great importance, as landmarks for guiding the march of troops.

103.—Specimen of the Reconnaissance of a Road.

(Plate X.) In order to exemplify the proper arrangement from the memoranda made in the field, a complete report on a road is

annexed for reference. This reconnaissance will be found to include most of the subjects likely to arise in reporting on a road. It embraces about four miles of ground, which is the extent at present authorised as the test in the Army Examination, and has been here drawn out on a scale of 2 inches to a mile.

In elementary practice the details should be entered into more fully than would be the case when larger reports were attempted after proficiency had been attained; but by doing so at first on small pieces of ground, it will be found very easy afterwards to generalise on an extended tract of country.

Although the information has been already given under the proper headings in the last Section, attention will now be called by actual reference to the tenth Plate, to such points in making a road reconnaissance as those in which difficulties and errors are likely to arise.

The reference numbers are always entered upwards, in the order in which the ground is gone over, and are marked I., II., III., &c.

The different stations, if not at some place already named, should be so called that any intelligent officer will easily recognise them; care being taken to apply the local and adjacent objects in these appellations as much as possible, as "Radnor Bluff," "Crinchley Road."

In filling up the intermediate distances it must be observed that they will only be entered between stations on the direct line of route, as between II. and IV., or IV. and VII.; otherwise an erroneous conception will be conveyed of the true distances from the starting point.

By having the supplies, transport, and water still further tabulated and arranged as has been done in this specimen, great facilities for reference as to quantities, and at what points they are available, are attained. Those which chance to exist at some distance from any station are grouped on to the nearest station; if thought necessary, the words "at" or "near" may be prefixed to the number of any station.

The following are the formulæ most necessary to remember in making reports on roads and rivers:—

For the number of inhabitants:—Allow 5 people to each small house, and 10 to each larger one.

For temporary accommodation for troops:—Multiply chimney-

flues by 6 for the number of men; or allow 25 men to each small house, and 100 to 200 for each larger one; or for large buildings take a quarter of the number of square yards in the ground plan for the number of men per storey.

For accommodation for horses:—Allow 2 horses to each small house, and 10 to 20 for each larger one; or half the number of yards in the length of an outhouse gives the amount of stabling; if 8 yards in width, allow for 2 rows of stalls.

For the contents of stacks:—Multiply the height, breadth, and length together, and divide by 11 for the number of tons of hay.

The same multiplied together and divided by 16 for the tons of straw.

For the acreage of crops:—Divide the area in square yards by 4840.

For supply of water:—Multiply the breadth, depth, and velocity in feet for one minute, multiplied by 900, to find the number of men for whom there is a supply of water.

For the breadth of a river and the velocity of the current:—Take up a position opposite some well-defined object on the farthest bank (see Section 51); pace off, if possible, at right angles along the nearest bank, leaving a mark at the half distance as well as at the full distance; pace again at right angles from the river, till the object on the farthest bank and the half-distance point are in one line. By now pacing back to the full-distance point, the breadth of the river will be found. The velocity of the current in yards for one minute, multiplied by 60, will give the rate per hour.

RECONNAISSANCE OF RIVERS.

104.—Object of Reconnoitring Rivers.

The object of the reconnaissance of a river is generally for the purpose of ascertaining how it may be crossed by an army or to oppose the passage of an enemy.

Information as to the breadth, current, and overflowings is required for the formation of bridges. The last is in addition wanted for the arrangements for defence.

The report is not drawn out in a tabular form, but has the marginal entries given in the "Details of Report," Section 106.

105.—The Sketch.

(Plate XI.) The sketch should in every particular agree with the instructions alreadv detailed for Road Reports in Section 101.

106.—The Details of Report.

(Plate XI.) *Breadth.*—The breadth of a river should be taken by one of the problems for finding the distance of an inaccessible object from a given point, as explained in Section 51.

Depth.—The depth should be measured from the surface of the water to the bottom, and information obtained as to its variations at different seasons, its liability to floods or to dry up, and to what extent it is exempt from freezing.

Current.—The direction of the current should be given, and the average rapidity found by a float on the stream for one minute. This distance in yards, multiplied by 60, will give the rate per mile for each hour.

The following is the generally accepted description for different velocities :—

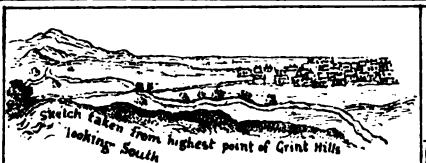
1 mile per hour	Sluggish.
2 „ „	Ordinary.
3 „ „	Rapid.
5 „ „	Very rapid.
6 „ „	Torrent.

Channels.—The number of channels should be stated, with the position and size of islands, and the nature of the bottom.

Banks.—The height of the banks, from the top to the surface of the water, with their steepness and formation; also, if one commands the other, and if they could be easily cut down.

Bridges.—The construction, stability, dimensions, and defensibility of the bridges must be reported on, with the means of repairing and destroying them, and of the places and materials for constructing new ones.

Fords.—The depth, breadth, nature of bottom, and rapidity of current of the fords must be examined, with their direction across



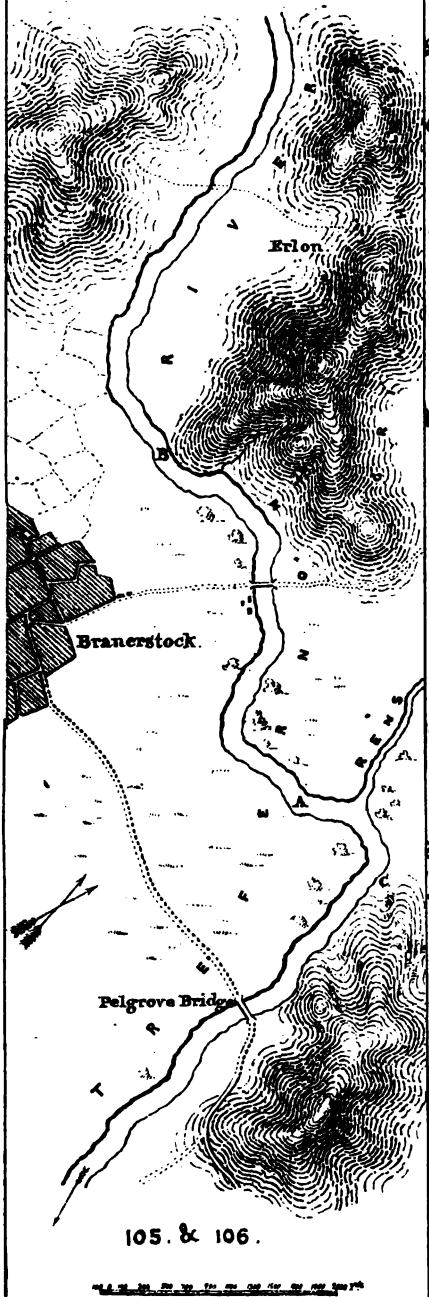


PLATE XI.

Reconnaissance of part of Trefernon River.

Breadth:— The River varies from 200 to 350 yards in breadth between the points laid down on the sketch and receives as tributary the Rens, about 2½ miles up, which is itself about 50 yards broad.

Depth.— The depth at the deepest parts is about 15 feet but on an average it does not exceed 10 feet; except in the spring months when it is liable to floods to the extent of about 15 feet more. During the severest winters it is occasionally covered with ice 1 inch thick.

Current:— The current flows in a southeasterly direction sometimes tending to east. In the bends reentrant to the stream it sweeps round at the rate of 3 miles an hour but in most parts it runs at only 2 miles an hour; two rapids however exist the one at point marked A and the other at B where it passes at 4 miles an hour.

Channels:— There being no islands it has only one channel and the bottom is muddy except at the two rapids and near the village of Erlon where it is composed of boulders, occasionally mixed with gravel.

Banks:— The banks are about 6 feet in height with the left bank usually preponderating over the other. They slope down at an angle of 36° to within a foot of the surface of the water where the slope increases to from 50° to 70°. Being formed of soft earth covered with turf they could be easily cut down.

Bridges:— Pelgrove bridge is strongly constructed of brick on 7 arches enclosed by parapets 4 feet high; length 200 feet; breadth 30 feet; depth from crown of centre arch to the roadway 4½ feet. It is thoroughly commanded by the heights opposite to it on the left bank at a distance of half a mile. Another smaller bridge stands immediately to the north of the town of Branerstock: this is of stone very old, although still strong, with a roadway of 22 feet but rather steep. At C the river being only 180 yards broad, would be a suitable point for constructing a new bridge, and from being at a reentering bend and commanded by the lower spurs of the hill near it would have the additional advantage of being easily defended. Materials for repairing the bridges can be obtained from the rocky parts of the hills immediately adjacent in each case, and from the scattered trees which are to be met with near the banks of the river.

Fords:— The only ford is opposite to the village of Erlon with a direction N.E. to S.W. across the stream; depth 3 feet; breadth 220 yards; nature of bottom hard gravel; current 2 miles an hour. It is practicable for Infantry and Cavalry except during floods, and the banks slope gradually down to the water on each side. A fortpath leads to the river at this point.

Ferries:— There are no ferries established on the river within the extent of the sketch.

Navigation:— The river is navigated by some 15 barges varying from 20 to 40 tons in burden, which are principally employed in bringing up supplies of coal for Branerstock which are landed on the right bank at wharves below the bridge. A few sailing and pleasure boats are used on the river.

Country:— The country on the left bank is hilly and thoroughly commands the town in front and the river throughout its whole extent: these hills rise from 200 to 250 feet above the river. The ground on the right bank is flat with the exception of a gentle rise about 2½ miles to the N.W. of the town in which direction it is also much intersected by the hedges of the cultivated land. The main road crossing Pelgrove Bridge is 36 feet wide, well macadamised and not confined by hedges or banks as it passes over the open ground before entering the town. From the bridge it leads to the south east for nearly a mile where it breaks into two roads. The main one proceeding round the foot of the hills with enclosed hedges and a branch one striking off to the southward following the left bank of the river. The road entering the town from the north is not in such a good state of repair and is rather contracted near the bridge. No good point exists for forming an inundation. Branerstock is an open town with about 20,000 inhabitants, 12 Churches and 4 Public Buildings. The houses are well built of brick. Erlon is merely a scattered hamlet of 6 houses. The open common to the east of the town would form a good position for an encampment.

the stream, and if always passable. The maximum depth for infantry is 3 feet, for cavalry 4 feet, and for artillery 2½ feet.

Ferries.—The number and size of the boats at the ferries must be found out, with the time occupied in crossing, and the means of landing on each side.

Navigation.—The powers of navigation on the river must be discovered, between what points it exists, for what tonnage of vessels, and the number and size of boats available.

Country.—The natural features of the surrounding country, the power of forming inundations, and the roads leading to the river must be brought to notice; with remarks on canals, lakes, towns, villages, and military positions in its vicinity. The means of attack and defence of the river must be fully reported on.

RECONNAISSANCE OF OUTPOSTS.

107.—General Object of Outposts.

An army is invariably covered by outposts, for the purpose of insuring safety by preventing surprise, thereby enabling the main body to be properly formed up before receiving an attack.

A system of outposts consists of infantry piquets, with double sentries in front and supports in rear; cavalry vedettes in advance, and patrols still farther in front.

108.—Selection of Ground for an Outpost.

There are certain general principles which must be attended to in placing an outpost.

An outpost should rest on some natural obstacle, and should overlap the flanks of the main body. It may, as a general rule, be three-quarters of a mile in advance; but in very open ground this may be extended to even three miles. The proportion of infantry, cavalry, and artillery will depend on the nature of the ground; the more enclosed it is the more there will be of the two former, and less of the latter.

Every vedette, sentry, and piquet must be able to see and com-

municate with each other, and observe every movement of the enemy, but not be seen themselves; a hundred yards being laid down as an average distance. During the day the chain of sentries is to be placed on the higher ground, but at night they should be drawn in below the hills, and extended again to the tops at daylight.

A piquet and its sentries should be on the same side of a river; cavalry may cross beyond the impediment; the support to be three times the strength of a piquet.

109.—Placing of Outposts in a State of Defence.

A post should be strengthened by barricading roads, destroying bridges, loopholing walls, throwing up breastworks, cutting abatis, and forming every kind of available obstacle. No obstacle should, however, be permanent, in case the army wishes afterwards to advance.

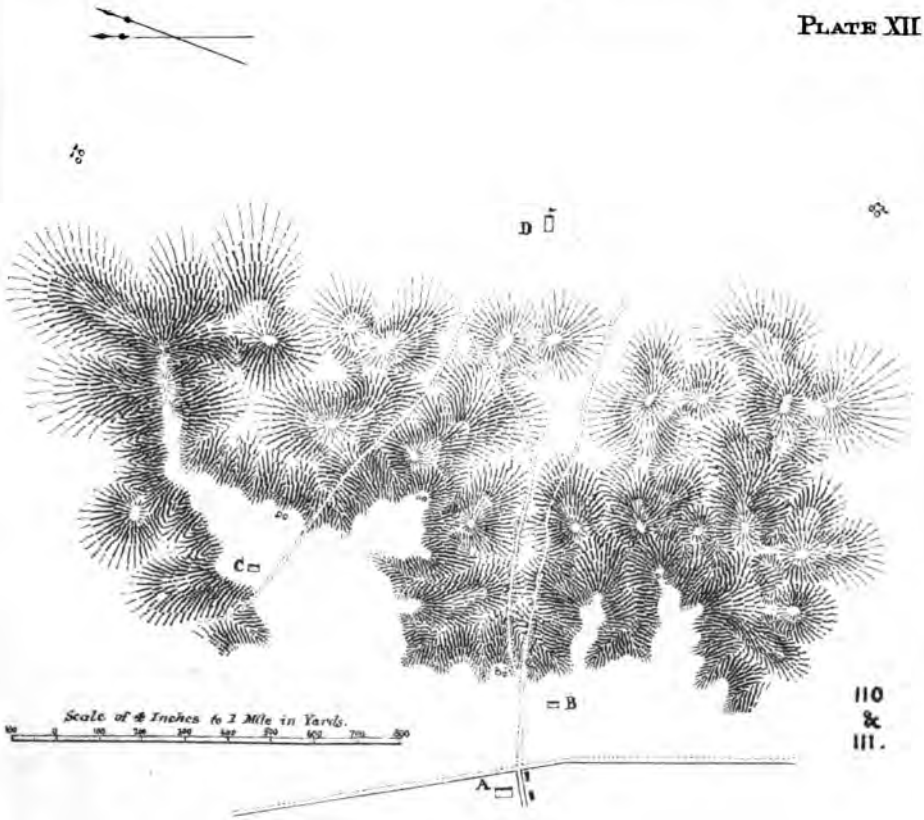
Houses may be advantageously brought into the line of defence by having them properly prepared; about six feet of wall space on each storey being allowed for each man, with, in addition, a reserve of one-sixth of the whole. No piquet must, however, without special orders, shut themselves up in a house, but they must retire when a serious attempt is made to surround them.

All outposts must be under arms an hour before daylight, and patrols must be sent out once between each relief of sentries for the purpose of examining the ground in their vicinity.

110.—Outpost Sketching.

(Plate XII.) Every officer is expected to be able to make an intelligent sketch of the ground in the immediate vicinity of any piquet or outpost on which he may be placed, together with the proper conventional representations of any obstacles or intrenchments he may have found necessary to construct for the purpose of strengthening his post.

The sketch is to be performed as an "eye-sketch," according to the principles laid down for this branch of instructions (Sections 85 to 88). Should an officer not have acquired that information,



Outpost Sketch and Report.

Ranks.	Cavalry.	Infantry.
Officers.	1	6
N.C. Officers.	4	12
Buglers.	1	3
Privates.	20	160
Horses.	26	2

The Outpost was detailed to watch the open country lying immediately under an abrupt ridge of hills of about 150 feet in height, covered with heath and having open and occasional marshy ground in front. The position for the support of one Company was selected at the junction of a road on the plateau about a quarter of a mile in rear of this ridge with the open track leading up over it from the country in front. At this point also stood a few Mud-built Cottages, the front one of which was at one loopholed on its exposed side. Good wells of water were found in the gardens attached, together with a small supply of brush-wood which was employed to strengthen the defence of the bank enclosing one side of the road.

Two piquets were thrown out consisting of half a Company each, the right one securing the road at B where the track crossed the crest of the hill immediately in front of the support. The left one was placed in the vicinity of a side road at C about half a mile to the North-east. They both stood on the plateau opposite two main re-entrants of the hills, withdrawn from the crest.

Three market sentinels projecting into the valley at about equal distances of 600 yards apart were occupied by double sentries, who with two pairs of connecting sentries were able to command the whole of the intermediate ground, and were sufficient to watch the approaches intrusted to the Outpost by day. They were thrown forward along the paths to the foot of the main slope during the night.

The Detachment of Cavalry was sent forward to patrol the ground towards D, with scouts still further in advance.

Patrols were sent out between each relief and constant communication was kept up with the Outposts on each flank.

Detail of the Force is given in the margin.

The troops went on duty at an hour before daylight on the 18th inst. relieving the 3rd Brigade of the 1st Division, and came off duty at daylight on the 19th when relieved by the 2nd Brigade of the 2nd Division.

Nothing particular to report during tour of duty.

W.

he will nevertheless be called upon to make the sketch to the best of his ability. He may also add landscape drawings to elucidate any point.

The scale is not to be less than six inches to a mile, but it will generally be found convenient greatly to extend this size.

It is necessary to ascertain the names of villages, detached houses, woods, streams, heights, and mountains within rifle range, or even beyond it; also their approximate distances.

The situation and distribution of all his men must be carefully fixed on his sketch. The troops and fieldworks will be represented as laid down in Section 29, it being remembered that troops on duty are not considered as encamped. The plan of surveying any intrenchments will be found in Section 93.

111.—The Report.

(Plate. XII.) The report should include a description of the ground, the roads leading to it, and obstacles caused by the nature of the country; the proposed modes of attack and defence, with the number of men and their distribution; the nature of works for strengthening the position, with calculations as to labour and time required; the means of effecting a retreat or advance.

RECONNAISSANCE OF POSITIONS.

112.—Different Kinds of Positions.

In reconnoitring a position, it is supposed to embrace a sufficiently large extent of country for the occupation of a whole army corps.

Positions are divided into two classes, defensive and offensive. In the former case the reconnaissance must include all roads leading to the position, and in the latter all those leading from it. These roads must be respectively commanded by the positions.

113.—Selection of Ground for a Position.

A hilly country is the best for a position, but a flat country may be chosen if it is intersected by obstacles.

A position should resemble as much as possible the general outline of a front of fortification; that is, it should consist of natural projecting bastions joined by withdrawn curtains on the same level. If no natural projections exist, then farms, villages, or fieldworks may be held in force in order to remedy the defect.

The following are the conditions which should be attempted to be attained in the choice of a position:—

An uninterrupted view of the movements of an enemy.

An extent proportionate to the strength of the force.

The nature of the ground suitable to the description of arm.

Not commanded in front or flanks by ground within cannon shot, nor the latter enfiladed.

The flanks and rear secure, by resting on obstacles, either natural or artificial.

To command approaches as well as lines of retreat; the communications in rear being uninterrupted by obstacles.

The different parts not divided by any impassable river, ravine, or morass; but the front covered by these obstacles.

To be of sufficient depth, and so open in front as to enable an army to assume the offensive at any moment.

An officer, before deciding on a position, should imagine himself in the enemy's place, and consider how he would act under these circumstances.

114.—Occupation of Ground.

The number and description of troops, and their distribution, depend on the extent, strength, and nature of the ground, and the number of the enemy.

An army is generally drawn up in three lines, with a reserve of about one-fifth of the whole, and one-third of the guns.

5200 infantry in line two deep occupy about a mile, or 10,000 men for every 1000 yards is generally allowed for the three lines inclusive. The proportion of cavalry is one-sixth to one-eighth that of the infantry, and the number of guns is from three to four for every 1000 men.

In a defensive position, infantry may vary their formation from line to column, and not continuously, but be drawn up to suit the natural inflexions of the ground.

An army drawn up in only two lines, requires six hundred yards of depth for manœuvring.

If a position is to be occupied for some time, it must afford access to fuel and water.

Encamped troops occupy the same frontage as when drawn up in order of battle.

The advance to attack in front of a position, will be made by the infantry in line.

115.—Distribution of Troops.

Infantry should line the heights and occupy broken and enclosed ground, woods, and houses.

Cavalry should be employed in the plains, on open ground, and on the flanks and other situations from which they can charge suddenly on the heads of columns trying to establish themselves.

Artillery should be posted on gently commanding ground where the slopes are exposed to the full sweep of the guns, on all roads leading to the position, and on the salients and flanks, so as to give a cross-fire. The guns should be slightly withdrawn from the crests of the hills, and the ground at the foot should be enfiladed by guns on either side. Their fire should be always concentrated, and if one flank is not very safe, the greater part of the guns should be placed on a secure position to cover the insecure flank.

The key of a position and all open ground should be occupied in force with reserves at hand. Behind streams, marshes, or broken ground smaller forces should be posted, principally composed of skirmishers, with a large proportion of guns.

The two front lines of an army should be from 200 to 300 yards apart. The reserve should be 1000 yards in rear of the second line; but during an action it should close up to half that distance.

The second and third lines are usually of the same strength as the first.

The reserve should be in column in rear, out of fire, and in a central position for re-enforcing.

In a plain the flanks of skirmishers should be protected by cavalry, which arm should so protect all positions, but be well in advance of it.

All posts should be artificially strengthened, in addition to what already naturally exists.

116.—Space Occupied in Line by each Arm.

Two feet in breadth are allowed for each infantry soldier; and as the British are drawn up in two ranks, by dividing the number of men by 3 will be found the number of yards occupied by each battalion. To this must be added 8 yards for officers and colours, and 25 yards for interval on the flanks.

Cavalry requires one yard for each horse in the front rank; therefore, dividing the men by 2 will give the number of yards. The squadron intervals are $12\frac{1}{2}$ yards.

Artillery guns or waggons, each with 6 horses, require a space of 15 yards in column of route, with 4 yards extra between each. These spaces are retained by guns in position, with an interval and a half or $28\frac{1}{2}$ yards on each flank.

(Plate IX.) The space occupied by a brigade consisting of a battery of artillery, two regiments of infantry and one of cavalry drawn up in line, and of the undermentioned strength, would consequently be half a mile in extent, which may be thus calculated:—

1 Battery of 6 guns, 19 × 5	= 95	yards.
„ intervals $28\frac{1}{2}$ × 2 . .	= 57	„
2 Battalions of 630 men, $\frac{630}{3}$ × 2 . . .	= 420	„
„ officers and colours 8 × 2	= 16	„
„ intervals 25 × 2 . .	= 50	„
1 Regiment of 4 squadrons, each 96 men, $\frac{96}{2}$ × 4	= 192	„
„ intervals $12\frac{1}{2}$ × 4 .	= 50	„
Total	880	„

117.—The Sketch of the Position and the Report.

(Plate XIII.) The ground should be surveyed and the report drawn out for a position, exactly as has been laid down for an outpost in Sections 110 and 111; only that as a position is of the greater consequence, more time will most likely be allowed for its preparation, and instruments may be employed for surveying it. The officer will, in addition, be specially selected; and as he will not have the charge of troops, his whole attention can be devoted to its execution

Winchester. PLATE XIII.

utline.

th. Winchester affords a good point to act from for the purpose of checking its still further
he south, diverging again into the heart of England, with direct Railway commun=
n by passing it, he would not only have his flank exposed, but his communications
most to a certainty march along the coast to Southampton, and having brought
s off, by the Gosport and Southampton Roads and the Railway.

Open Downs, interspersed by patches of cultivated land divided only by earthen
ing features of the chalk formation. Trees exist only in two Clumps, in the
s Battery; besides a few in the Town and at the Villages. The River Itching
he centre is a clear small stream, with a plentiful supply of good water,
for barges from Southampton, where it falls into an arm of the Sea. It is
six feet deep, flowing in several different channels through marshy
and is crossed by substantial bridges. The Roads are all very good and
ncluding the bye roads practicable for Guns. The houses are built of
tantial stone or brick-work. There are several large buildings
he Town itself, of which the most important are the Cathedral Barracks,
l, College, several Churches and Charity Hospitals, besides the usual
ublic Buildings of a Cathedral County Town. Of the Villages, St: Cross
the most important, and contains a large Church and Almshouse;
ll the others without exception having at least a Church which
could be rendered available for Military purposes.

Proposed line of Defence. — Plenty of time having been given to prepare
for the attack, a general line of defence ought to be taken up, about a mile
to the south of the Town; the extreme right resting on the Romsey Road
and the left on the Portsmouth Road; both of which, from the open
nature of the country offering no natural obstacles would have
to be strengthened by very strong Redoubts. The Village of St: Cross
would be the centre, advantage being taken of two ancient earth-
-works; one on St: Catherines Hill formed by the Romans, and the
other Oliver Cromwell's Battery, constructed by the Protector when
he besieged the Town in 1645. The principal weakness in the Position
consists in the marsh dividing its two wings, but this is greatly count=
eracted by the four good roads of communication across it in the rear.

The Defence.

Field-Works. — It is proposed that a large Redoubt should be thrown up
n the left above Longwood Warren, so constructed as to command the
rtsmouth Road, and the long Valley reaching down to Twyford. The old
rse-shoe shaped Earthwork on St: Catherine's Hill might be rescarped
d a Redoubt constructed within it on the natural rise of the ground
e top of the hill which would give it sufficient relief. The Clump of
n the centre when cut down would form abatis in front. One or more Batteries
uns if brought forward about 500 yards to the left front of this point would not
r the Road below leading across the marsh, but would be within range
Villages of Twyford and Morested. The walls which surround St: Cross
should be loopholed and the Church put in a state of defence. The marsh
ight be inundated by merely stopping up the arches of the two bridges
raised cross-road before these buildings. The spur of ground half a
th of St: Cross should be strongly held by Artillery to sweep Shawford
he intervening Downs and the roads from the South. Cromwell's Battery
made the Redoubt of a larger Work round it, constructed to cover the Village
he open valley leading to the south west. In this case also, trees will be found
e worked into the defences. A large Redoubt should be established on the top of the hill round
to cover the extreme right, with a Battery still further retired. The different Batteries
d by Parapets and Shelter-trenches prepared for the Infantry wherever exposed. The
drance to form the line of Outposts and to be fortified by such means as may be
. The bridges at Twyford and Shawford must be broken.

n of Troops. — The Morested Outpost might include Longwood Warren and Hasley Down,
take in the Villages of Shawford and Compton, and the Pit Outpost the remainder of the ground
ould require one Battalion of Infantry and one Regiment of Cavalry. One Brigade would be drawn
Redoubt; and the other Brigade of the Division in Reserve at Chilcomb with its Cavalry thrown out
y St Catherine's Hill and St Cross with a Brigade in each. The remaining Division would take Cromwell's
pying these Works. Each Division will supply its own Reserve and a large number of Guns must
ed by any available Battalions of the least disciplined Troops.

he Attack.

ore he reached the ground shown at the bottom of the Sketch, would most likely decide
the Wings his Flank being in either case comparatively protected by the River.
Twyford side as from the cover afforded by the steep ground he might press
the Road to London over Magdalen Hill. With this view having driven in the
on by Morested up Longwood Warren and make his chief attack on the Redoubt
turn his Flank, whilst the Troops on Twyford Down assisted by the Redoubt would
d be able to retire through the Town by the Roads to Salisbury, Andover and
ital by taking up a fresh position still further in rear.

Wm Paterson
Captain, 60th Kings Royal Rifles.

ADDENDA.

118.—Plane-Table.

The plane-table is an instrument of simple construction, used principally for filling in the minor details of military sketches. The French having lately applied a simpler method than that previously in use for attaining the power of revolving the instrument, with less weight of metal and a broader basis for insuring stability, which, with certain improvements, there is every prospect of soon being introduced into our service, it will be preferable to explain it, although the principle will of course be the same whatever one is used.

(Plate XV.) It consists of a drawing-board, A, 12½ by 15 inches in size, provided with recesses, B, C, in the edges to secure the framework, D, E, &c. Under one side is a compass-box, F, with the power of being drawn out till it partially shows the needle, or when not required able to be removed altogether. The centre of the underside of the table is provided with a groove, G, covered by a flat piece of metal, which enables a broad-headed axis, H, to work horizontally after projecting through the socket in the cap of the tripod legs, J, which are fixed into movable joints.

A sheet of drawing-paper is cut one inch larger each way than the board, with triangular snips made in each corner, and then the board is placed face downwards on the paper, which is pressed in by the pieces of framework which fixes it by brass clips, K. By this plan the whole of the surface of the drawing-paper can be utilised without any projecting impediments.

To set up the instrument, one of the legs must be held in each hand, and the other thrown out till the table is adjusted as nearly as possible in a horizontal position over any required point on the ground. By releasing the spring, the traversing of the compass-

card on its pivot will aid this process, which is attained when the table turns freely on the axis of the groove.

Upon the first occasion of using the plane table on a new sketch, the north point must be laid down on the paper by the following process:—The table, having been revolved till the needle of the compass corresponds with zero (or, if preferred, the compass reading merely noted at whatever position the table may be standing), the axis must be clamped by the screw underneath to the cap of the legs, and a line drawn on the paper parallel with the magnet of the compass.

The point on the paper for beginning the sketch having been decided on, as noted in the first paragraph of Section 84, a ruler with raised sight-vanes laid on the board has an edge near one of its extremities brought to the point round which it is to be turned, by looking along the edge till it lies in the directions of any required objects, when pencil lines must be drawn in succession on the paper in these directions.

The plane-table now being lifted, the distance along one of the lines as a base may be paced, and the instrument set up on the back-station, as already explained for the line AB in Section 85.

The rest of the processes employed in using the ruler on the plane-table have previously been given in Sections 85 and 86; the clamping screw being in every case released when it is required to revolve the table for the purpose of adjusting it, such as in the case of directing it on a back-station.

The compass-card should be clamped before moving the plane-table, and only when such rare exceptions occur as when any grave error has arisen in the work not again released, in order to avoid the inaccuracy of depending upon it, when a better result can be reached by working by the back-stations alone.

The order of conducting a sketch with this instrument will of course not vary from the principles already given in Sections 76 to 84, although the relative positions of objects will be accurately laid down by the help of only a ruler, instead of by a prismatic-compass and protractor. It has the immense advantage of showing at once on the paper the angles between objects, instead of first having to observe them with one instrument and to lay them down with others; to say nothing of errors becoming by this means at once apparent, rapidity of execution is greatly increased. The dis-

advantage is want of portability, which has been overcome in the system of sketching without instruments (Sections 85 to 88), where the whole of the principles of the plane-table are applied.

The top of the new plane-table is so constructed as to form the best kind of sketching-case for other purposes.

119.—Stump Shading.

In the third paragraph of Section 2 the principle of this method of expressing ground was explained as applied with a brush, but it has lately been proposed that, in consideration of the exigencies of time, the same plan might to a certain extent be carried out with plumbago and a stump or washleather.

(Plate XIII.) The outlines of the features of ground having been sketched in pencil in the usual way, as explained in Section 24, or the contours laid down on the paper, a blacklead pencil is rubbed backwards and forwards on the different slopes, according to their steepness, in the general direction of horizontal shading.

Some powdered blacklead or the rubbings from a pencil are then spread on a piece of coarse waste paper, and one end of a leather stump is well charged with the powder by rubbing it into it.

The rough shading on the drawing is then rubbed in and diffused with the blackened stump, softened off where necessary with the other end; the process being repeated till the proper depth of shade has been obtained.

The instructions previously given with reference to horizontal shading in Sections 5 and 6, as to working from the higher hills downwards, from the re-entrants to the salients and towards the draughtsman, equally apply to this system; in fact, the more closely the stump is used in the true direction of contours, the better th effect of the shading.

When the hills are finished, the different conventional details must be permanently brought out, either with pencil or Indian ink; but it would seem even more appropriate if they were put in their proper tints (Sections 27 to 29) with a brush or coloured pencils, thus assimilating this system of drawing more closely to that of "brush-work."

Some draughtsmen, instead of using a stump, employ a piece of chamois leather or flannel; but the process will be found more

difficult when working on small scales, besides soiling the fingers and possibly the drawing more than by the previous method.

All obliterations, whether of mistakes or too great depth of shading, will have to be removed either by Indiarubber or stale bread-crumb worked slightly in the fingers.

After the sketch is completed, it may be fixed with a coat of weak gum-water or isinglass, to prevent its rubbing off.

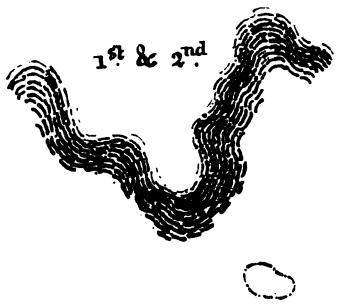
120.—Range Finding.

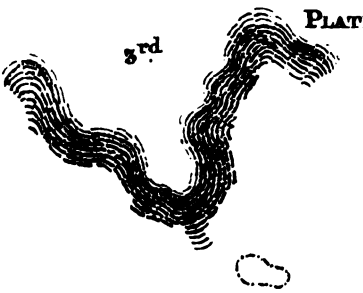
When it is only required to find the length of one or two distances, such as is occasionally the case in reconnoitring and in discovering the ranges for different arms, without reference to the intermediate ground, a range-finder may be employed.

(Plate XV.) They are all more or less worked on the theory of finding the dimensions of a small triangle, from which to obtain those of a large similar one—the defect of which system is, for the reason already given in Section 42, that the necessary smallness of the base, in comparison with the distance of the required object, is liable to be a material source of error; as well as the employment of reflecting mirrors, which constantly get out of adjustment. The necessity for attaining the following conditions whilst making observations also gives trouble, if they are not even impracticable in many cases. By most of the methods, not only must the object, O, be seen from both ends of the base, CA, but at the same moment the other end of the base must in each case be visible; whilst, in addition, the base must be at right angles, OCA, to one end of the range, with the still further power of again measuring off AB at right angles, CAB, to the other end of the base.

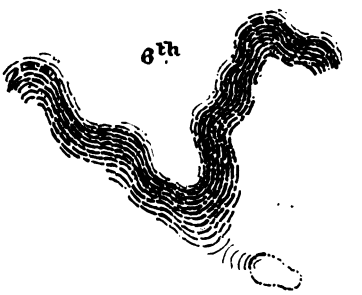
For ordinary surveying purposes distant points would be more accurately fixed by a regular series of triangulation (Sections 38 to 42, and 76), as where that had already been laid down in working a sketch, the position of the observer could at any moment be discovered with great accuracy by interpolation (Section 44); thus saving the services of an assistant, the carrying of one or more extra instruments in the field, and the loss of time entailed in taking observations with a complicated range-finder; besides which, not only by the former process would the one distance

PLATE XIV.





Sections,



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&

25.

be obtained, but by measurement from the sketch the relative positions of every other object.

The Watkin range-finder is the present authorised instrument for the use of the army, and the following are part of the instructions which are issued with it:—

"*Adjusting the Instrument.*

"Open the lid by pressing the spring, and see that the brass cylinder is screwed up as far as it will go, thus setting the instrument at zero. Press the sliding collar (in the centre of the instrument) back to the stop, that is to 6 on the scale, and move the horizon glass arm until the screw presses against the steel inner block. When in proper adjustment the mirrors on the index and horizon glasses are now parallel.

(PLATE XV.) "Taking the Range:—*Case I. Where the base is between* 60 *and* 120 *yards.* Suppose the distance from A to O to be required.

"At *Take the Range.* No. 2 plants a picket with square leather head and strut (three of which are provided with the instrument) at A, the flat side of head turned to the left and the strut to the rear. No. 1 notices what portion of the object he can see from A, goes off about 100 yards to the left (if necessary, the right angle can be laid out to the right, and the range taken to the left, by reversing the operation herein detailed), at about right angles to AO. He opens the instrument, pushes the arm against the side stop (by moving the button), turns instrument upside down and looks through the end eyehole at object, through the plain part of the horizon glass.

"The picket will appear reflected in the silvered part of the glass; should it appear to the right of the object he must retire, if to the left he must advance, until the picket A exactly coincides with some well-defined portion of the object. He then plants the picket C between his toes, and should verify the accuracy of the observation by resting his hand on the top of the picket and looking through the instrument again; any slight error can then be rectified by forcing the head of the picket to or from him.

"No. 1 has thus planted the picket C at the right angle between O and A. In other words, OCA is a right angle.

"He now turns the box right side up, pushes the arm against

the inner stop (by means of the button), faces A with C exactly between his toes, and looks through the side eyehole, inclining the left end of the instrument slightly downwards. He will see the two pickets A and B (which No. 2 has in the meantime planted) through the plain part of the horizon glass, and their reflections immediately below them. He turns the cylinder to the left with his right hand, until he makes the reflection of the round-headed picket exactly coincide with the square-headed picket, and thus obtains the length of the base AC, which he reads on the cylinder. He sets the sliding collar to the same number on the brass scale.

"Meanwhile No. 2, as soon as he sees No. 1 plant his picket at C, lays one of the cross lines engraved on the head of the picket A on C, hooks an 18-feet wire cord to A, and stretches it to the rear in the direction given by the other line on the head of A, thus approximately setting off a right angle CAB. He plants B at the full extent of the cord, moves off to C, ready to bring in the picket as soon as No. 1 has completed the observation, unless there are more ranges to be taken from the same point.

"No. 1 moves to A, places himself facing O with the picket exactly between his feet, pushes the arm against the side stop as before, looks through the end eyehole at the object O, which he will see through the plain part of the horizon glass, the reflection of the picket C being seen in the lower or silvered part. He turns the cylinder with his right hand until the reflection of C exactly coincides with the object, and reads off the range opposite the arrow-head on the cylinder.

"*Case II. When the base is limited to under* 60 *yards.*

"The operation is similar to Case I., with these exceptions:—Set the sliding collar to 12 instead of 6, before making the pickets A and B coincide. The true range is half that read on the cylinder.

"*Case III. When the base is limited to over* 120 *yards.*

"This operation is similar to Case I., with these exceptions:—The base AB is made 36 feet (by hooking the wire cord and steel tape together, which fittings are supplied with the instrument), or the collar is set to half the base reading. The true range by either method is double that shown on the cylinder.

" *Use of Instrument for Surveying, &c.*

"The instrument can be used for obtaining the distance between two inaccessible objects, such as, AC from a point O.

"First find the distance CO in the usual way, set the cylinder to this range, and the arm against the inner block, look through the side eyehole and slide the collar until C is reflected on A. The reading opposite the arrow will be the distance AC. Should AC be more than 120 yards, set the cylinder to half the range and double the result. If less than 60 yards, set the cylinder at double the range and halve the result.

"By holding the instrument vertically, height of buildings, trees, &c., can be taken in the same way.

"The following table of angles corresponding to ranges will be useful in taking angles between objects for surveying purposes :—

Range.	Angle.		Range.	Angle.		Range.	Angle.	
yards.	deg.	min.	yards.	deg.	min.	yards.	deg.	min.
5000	1	9	2100	2	44	1200	4	45
4500	1	16	2000	2	52	1150	4	58
4000	1	26	1950	2	56	1100	5	11
3500	1	39	1900	3	1	1050	5	27
3400	1	41	1850	3	6	1000	5	43
3300	1	44	1800	3	11	950	6	1
3200	1	47	1750	3	16	900	6	20
3100	1	51	1700	3	22	850	6	42
3000	1	55	1650	3	29	800	7	7
2900	1	59	1600	3	35	750	7	35
2800	2	3	1550	3	42	700	8	8
2700	2	7	1500	3	49	650	8	45
2600	2	12	1450	3	57	600	9	28
2500	2	18	1400	4	5	550	10	18
2400	2	23	1350	4	15	500	11	19
2300	2	29	1300	4	24	450	12	32
2200	2	36	1250	4	35	400	14	2

"The method of proceeding is as follows :—

"Place the mirrors parallel, adjust the sliding collar to 10, look through the side eyehole and reflect the image of one object on to the other (as in taking the base) by turning the cylinder.

"Note the range on the cylinder, and take the corresponding angle from the table. Thus, suppose the reading on the cylinder to be 1000 yards, the angle would be 5° 43.′"

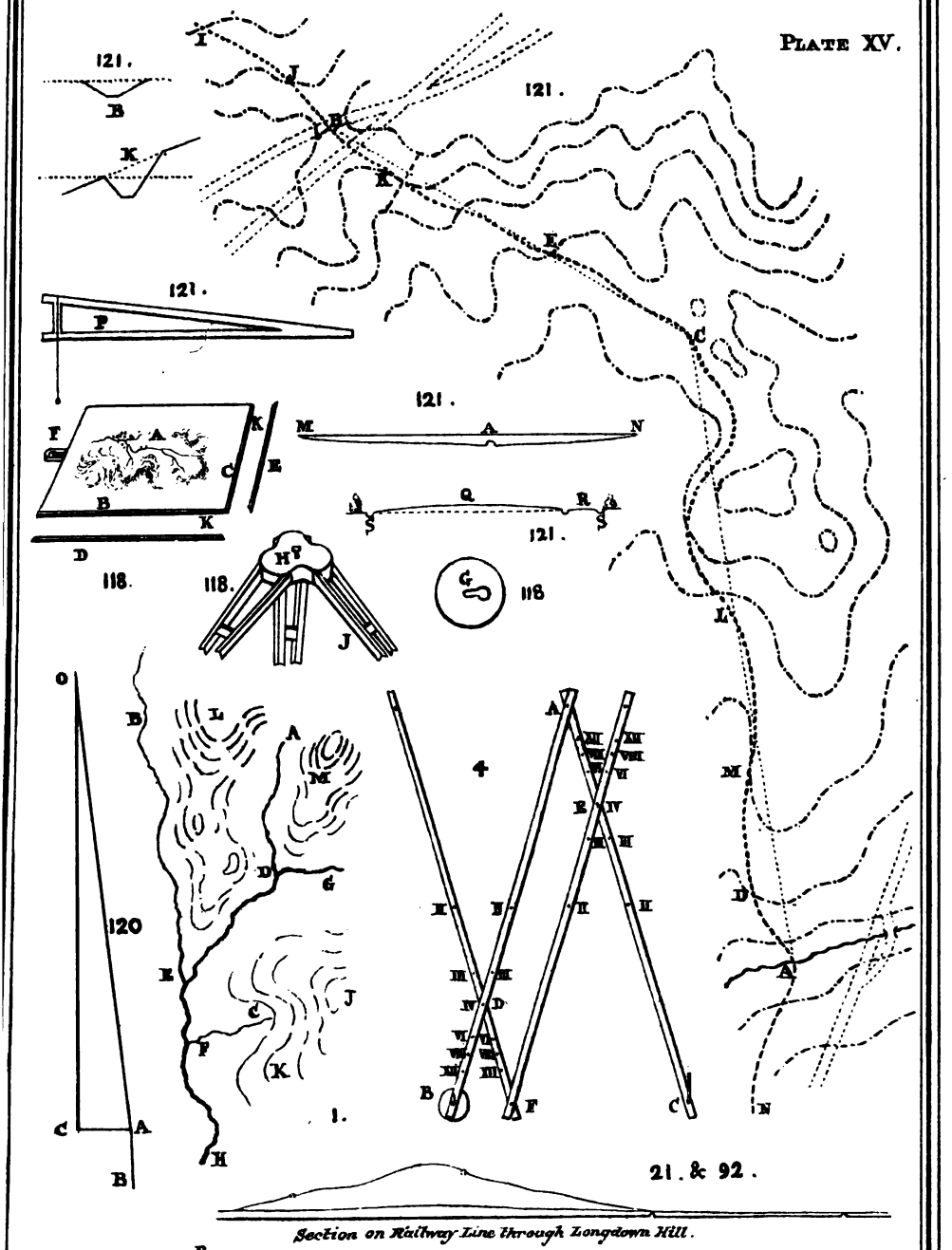
121.—Laying out Roads.

In the selection of a route between any two points, the straight ine would naturally be the most direct, but this would be restricted by the steepness of the declinations and any obstacles. The surface should be kept as level as possible, and for wheeled traffic the gradient of a little less than four degrees, or 1 in 15, may be taken as the minimum on roads of the very best construction, and one-twelfth of a degree, or 1 in 100, for railways. Time and economy must also be considered in the construction of cuttings, embankments, and bridges.

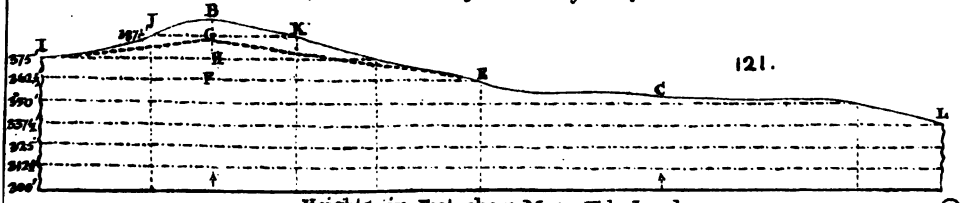
(Plate XV.) The first thing to be done after making a general examination of the route is to prepare a contoured plan of it with the ground on each side to a moderate extent. Let A and B be the two extremities required to be connected by a road, and as it is desirable to take advantage of the ridge joining the under features to the higher ground, mark a point C on the plan at the centre of the neck. Join the points AC, CB; and assuming that no slope is to exceed 2°, or 1 in 30, beginning at A, apply the scale of horizontal equivalents on the edge of the orometer, as explained in Section 15; or, if preferred, take the distance in yards corresponding with that slope from the table of gradients, in a pair of compasses, till a line is discovered as nearly coincident with AC as possible, on which the distance between each pair of contours shall at no time be cut at less than the distance of the horizontal equivalent. Repeat the process till the whole route has been traced on the plan; of course taking advantage of keeping the level as far as possible, and not permitting any rise in the ascent to be afterwards lost, by applying the knowledge already acquired as to passing up into the re-entrants and round the salients. The result will be a curved dotted line such as ADCEB.

A working section, as shown at bottom of Plate XV., must then be constructed on paper of the selected route in the usual manner (Sections 20 and 21); and in the case of there being cuttings or embankments required, it will be necessary to determine the quantities of material to be excavated so as to let the one compensate the other. This may be done by stretching a thread over the profile on the plan till by experiment the proper line is ascertained, when the dimensions being measured by scale, the profiles can be

PLATE XV.



Section on Railway Line through Longdown Hill.



Heights in Feet above Mean Tide Level.

calculated by Sections 61 and 63. The volume of earth must be taken by settling on the side slopes and making cross-sections where required, as at B and K, calculating as in Section 69. A table of the heights of the surface of the ground, as well as the formation surface of the road, can be drawn out from the section when it is finished.

The passing across other roads or rivers at any fixed heights above or below them is merely an incidental process, of which cross-sections, as MAN, must in addition be prepared, the minimum height for passing traffic over or under being generally 20 feet. Roads should, if possible, pass above any springs issuing out of the sides of a hill, and should always stand above the level of floods.

At present the difference in level between the valley and the top of the hill is represented by eight contours of $12\frac{1}{2}$ feet apart to amount to 100 feet, and taking the distance of the route as about 800 yards or 2400 feet; this, divided by the denominator of the ratio $\frac{1}{30}$, will give (by Section 84) 80 feet as the amount to which the rise must be reduced over the whole length, to bring the road down to a maximum slope of 2°. The result can be partly attained by a cutting at B for forming an equivalent embankment at A.

Take a point G on the profile under the highest part of the route at a little more than half the 20 feet to be got rid of, say at 12 feet, with such gradients drawn outwards that GE and GI shall be under $\frac{1}{30}$, which may be measured and thus calculated :—

$$\left.\begin{array}{l} GF = 22\tfrac{1}{2} \text{ feet} \\ EF = 300 \text{ yards or } 900 \text{ feet} \end{array}\right\} 22\tfrac{1}{2} \div 900 = \frac{45}{1800} = \frac{1}{40}$$

$$\left.\begin{array}{l} GH = 10 \text{ feet} \\ IH = 225 \text{ yards or } 675 \text{ feet} \end{array}\right\} 10 \div 675 = \frac{10}{675} = \frac{1}{67}$$

To find the area, proceed thus :—

$$\text{Contents of EGB approximately} = \frac{BG \times GE}{2} = \frac{12 \times 900}{2} = 5400 \text{ sq. ft.}$$

$$\text{,, BGJ ,,} = \frac{BG \times GJ}{2} = \frac{12 \times 300}{2} = 1800$$

$$\text{Available area from excavation } \overline{7200}$$

Now as 12 feet have been taken off the height of the hill, evidently 8 feet more will complete the required reduction of 20 feet; and dividing 7200 feet by 8 will give 900 feet, or 300 yards,

as the length of the embankment MAN at the point A in the valley.

When the route has been finally determined on, the surveyor proceeds to the ground with his map, and from its bearings and distances pickets out the line at about every 50 yards, or where any decided variation of slope exists, at still closer intervals, on the surface of the ground.

Should no contoured map have been previously prepared, the surveyor may stake out the ground at once, by merely settling on the route by taking the gradients as he proceeds, either with a clinometer or a rough plumb-level P, formed as in Plate XV., fixed at the maximum angle of slope.

The width of the road Q is afterwards marked out, giving 30 feet for main ones and 20 feet for cross ones, with at least one footpath, R, of 6 feet, and ditches, S, on each side to drain off the water. When the formation surface coincides with the level of the ground, this can be done at once; but when the ground slopes either in the direction of the road or laterally, the measurements for the surface widths must be taken from the cross-sections which have been constructed to scale at B, K, and A.

122.—Construction of Roadways.

The first thing to be done in the actual construction of a roadway is to bring the general surface of the ground to a level and to cut drains to carry off any water. In addition to digging deep drains on each side of the road, cross drains communicating with them may be necessary.

The main object being to have the foundation as solid and the surface as hard as possible, proceed as follows:—

1st. Spread a layer of turf or brushwood compressed to about 6 inches in thickness, and level this over with 3 or 4 inches of gravel.

2d. Fit by hand large flat stones touching one another, to a depth of 6 inches in the centre and 3 inches at the sides of the road; then fill the interstices with smaller stones. This will give a general convexity to the centre, for the purpose of shedding off the rainwater and preventing its soaking into the foundations.

Lime and concrete may be substituted for this part of the foundation.

3d. Lay down a coat of "macadam" 6 inches thick, the stones having been broken till they will pass through a ring of two and a half inches.

4th. Bind all over with 2 inches of clean gravel well rolled in.

The method of constructing any bridges which may be necessary must be obtained from works on the subject.

The surface of roads should always be exposed to the action of the sun and wind, otherwise the constant damp will cause them to deteriorate quickly. They should for the same reason, have the wet mud constantly scraped off and the drains kept clear. Care must be taken to have all ruts and hollows at once filled up and repaired.

EXAMINATIONS.

123.—Explanatory Remarks.

The best preparation for any competition being that of trial under as nearly as practicable the same conditions as are likely to arise whilst undergoing the actual ordeal, a selection has been made from the examination questions which have been put to the cadets, and latterly to the students, at Sandhurst; and in order that a fairer idea may be arrived at than would be the case if they were only taken from the ideas of any individual examiner, this collection of nearly ninety questions has been chosen from those which have been set by a number of different officers. The last two questions, here entered in their entirety, are examples of those given for entrance to the Staff College.

An opportunity is thus given to the student to test his own knowledge of the subject, by indicating the style and range of the study at present required in the army.

The numbers of the Sections are given, from which the questions were compiled, so that the answers may be discovered by reference to the work itself. In addition to which, Section 126 gives a summary of the answers to some of the questions where apparent difficulties have arisen.

124.—Precautions whilst undergoing Examination.

In all written examinations on the theoretical part of surveying, it will be found of advantage to look upon all questions at first in their simplest and most literal form, without searching for difficulties which in all probability do not exist; and where practicable to make diagrams in illustration of the answers, before explaining from these diagrams. The answers themselves should also be given as if the work was being explained to some one who knows nothing of the subject, but at the same time in the tersest form.

Before beginning to write out the answers, the time at the disposal

of the person under examination should be divided amongst the questions in proportion to their difficulty, so as to prevent the chance of the last questions not being answered from want of time.

After diagrams have been drawn, even although the question does not absolutely require it, it is sometimes desirable to give an explanation of the reasons for giving the answer in the way it has been done, as showing a more perfect knowledge of the subject; also answering questions in the order in which they have been stated on the paper, shows that the person under examination is more thoroughly conversant with the subject, and that no part is easier than another to him.

125.—Examination Questions.

Sections 81–84, 94.

(1.) An examination sketch to the south of the road from Frimley to the Chobham Ridges, including "Jack-Pond Hill," and extending about three-quarters of a mile along the road, and six hundred yards from it to the south.

Section 31.

(2.) Explain the method of keeping a field-book without reference to triangulation, accompanying the explanation with an imaginary example.

Section 34.

(3.) The compass reading of the zero-line being 35°, lay down the magnetic meridian and the true north line, assuming the survey to be made at Sandhurst.

Sections 44, 32.

(4.) Assume stations A and B at 4 inches apart, and B to be due east of A. From D the bearing of A is found to be 25°, and of B 55°. Find the position of D.

Again from A the horizontal angle between B and C is found by a sextant to be 60°, and the angle from B between A and C is 67° Find the point C. Ascertain also, and write down in yards, the distance between D and C, on the assumption that the plan is drawn to a scale of 8 inches to a mile.

Sections 15–21.

(5.) Fill in the accompanying contours (not given here) by scale of shade, and draw a section on the line AB. Scale 6 inches to 1 mile, contours 25 feet, heights to distances 3 to 1.

Section 78.

(6.) Show by a rough-drawn diagram how you would traverse a very irregular boundary or fence.

Section 11.

(7.) Explain briefly what is meant by a "scale of shade." Show as accurately as you can the character of shade you would use for the representation of each of the following slopes:—5°, 15°, 25°, 30°.

Sections 72, 73.

(8.) The backsight to A made with a spirit-level is 2.75 feet, the foresight to B 12.25 feet, the distance AB is 430 links; the backsight to B is 3.45 feet, and the foresight to C is 9.78 feet, distance 280 links.

Show how you would enter these observations in your book, and from the supposed book plot the section.

Sections 9, 54–59.

(9.) Explain the principle of construction of the eye-level (orometer) which you use, and how by its help you determine the contours in sketching ground.

Section 7.

(10.) Construct a scale of 6 inches to a mile, and give its representative fraction. The scale to measure yards.

Sections 34, 32, 37.

(11.) Plot the following traverse, showing the direction of the true north line.

From the point A at Sandhurst the reading on the horizontal

plate of the theodolite when the telescope is fixed on a distant point x is made 360°. The needle reading is now observed to be 23°. The following forward angles and measurements were then made with reference to the zero-line thus obtained :—

Forward Angle from		Distance from	
A to B	30° 15′	A to B	385 yards.
B „ C	18° 30′	B „ C	225 „
C „ D	48° 45′	C „ D	312 „
D „ E	150° 45′	D „ E	510 „
E „ F	115° 15′	E „ F	425 „

Section 10.

(12.) Construct a scale of "horizontal equivalents" on the following conditions :—

Scale 12 inches to 1 mile, contours 150 feet apart, slopes 32°, 17°, 4°, and 25°.

Section 36.

(13.) Give the reason why the numbers on your prismatic compass-card are inverted.

Sections 44, 81.

(14.) Of what use is "interpolation"? How is it carried out, and when is it applied?

Sections 81–84, 94.

(15.) An examination sketch of half a mile square, consisting of "Frith Hill." Scale 12 inches to 1 mile, contours 12½ feet apart. The positions of flags to be fixed by triangulation. Time 5 hours. The sketch to be given up finished on the ground.

Section 73.

(16.) Draw a section from the following observations, after completing the table :—

Distances in chains.	Back Station in feet.	Fore Station in feet.	Rise.	Fall.	Reduced Level.	
					Total Rise.	Total Fall.
4.50	6.25	3.24				
6.30	10.18	2.25				
5.20	1.80	13.45				
2.10	2.50	9.36				
7.60	2.20	4.40				

Scale for the horizontal distances, 4 chains to an inch.
Scale for the vertical distances, 10 feet to an inch.

Section 53.

(17.) The stations A, B, and C form the points of a triangle of which the side AB equals 620 yards, BC equals 513 yards, and AC equals 995 yards. From a point D, I observe that the angle between A and B is 32° 30′, and the angle between B and C is 38° 15′. Find the position of D and its distance from B. Scale 300 yards to an inch.

Sections 11, 15.

(18.) Give an example of the scale of shade which you have been taught to use, by its application in shading a slope represented by six contours. Let the shading extend over a width of $\frac{3}{4}$ inch of paper, so that the strength of the hachures and their distances apart may be fairly judged.

Section 81.

(19.) What are the different methods of obtaining the relative positions of points on the ground? Illustrate your reply by diagrams.

Sections 36, 93.

(20.) Two of the crest-lines of a fortification are observed to converge to a point on the side of the country. It is necessary to lay down on the ground the direction of the line which bisects the angle so formed. Explain how this may be done with the prismatic compass, without linear measurement.

Sections 42, 39.

(21.) What do you understand to be the best form for the triangles of a triangulation? Show, by a diagram, why very acute intersections of the lines forming the sides of the triangles are inadmissible. Draw a triangulation for a tract of country of 9 square miles in extent, to be executed on a scale of 6 inches to a mile. Scale for the diagram, 1 inch to a mile.

Section 18.

(22.) What is the meaning of the datum, when speaking of a section?

Sections 14, 47.

(23.) A hillside is found to have an inclination to the horizon of 27°; ascertain, by construction, the difference of level between two points 100 yards apart, measured on the slope at right angles to the direction of its contour lines.

Sections 13, 20.

(24) What is a contour? What are the three conditions necessary in making a section?

Sections 6, 25.

(25.) In model drawing how would you join a knoll to the higher ground?

Section 4.

(26.) Describe how you would proceed in copying a military drawing.

Sections 84, 76.

(27.) In a field-sketch, the angle of the base being 317°, where would you begin on the paper, and what precautions would you take in order to avoid confusing your lines of triangulation?

Sections 54–59.

(28.) What are the five necessary processes in laying down orthogonal points from the orometer?

Sections 27–29.

(29.) Represent the conventional signs for "troops in action," "water," "telegraphs," "cross-roads without hedges."

Section 34.

(30.) What do you understand by "Magnetic Variation," and at what rate each year does it change?

Section 41.

(31.) Show 1000 yards on a diagonal scale of 10 inches to a mile, reading to single yards.

Sections 76–80.

(32.) Having been directed to make a survey of about a square mile of ground, how would you proceed to carry it out?

Section 42.

(33.) Given the following conditions:—

Base AB = 1000 yards
Bearing of B from A = 290°
C due east of B = 350 yards.
D „ north „ B = 350 „
E „ north „ A = 600 „
F „ south „ B = 900 „

E cannot be seen from C or F.

To lay down the best series of triangulation under these circumstances. Scale 6 inches to a mile.

Sections 13, 11, 3.

(34.) Since the principle has been adopted of laying down contours on military plans, how can a general officer tell the adaptability of each part of the ground for the different arms of the service?

Sections 88, 34.

(35.) An "eye-sketch" having been taken at Hong-Kong, it is required to lay down upon it the two north points, under the supposition that the "variation" is 8° east. Describe how you would do it.

Section 54.

(36.) In getting in the conformation of the ground, what is the object in working strictly by the orthogonals and in not taking lines of direction with the prismatic compass?

Sections 27–29.

(37.) Give representations of as many of the conventional signs used in military surveying as you can remember, stating opposite each the object which you intend to delineate.

Sections 101–103.

(38.) Proceed to make a road report between the villages of Wokingham and Yateley, passing close to Sandhurst Church, over a distance of about 7 miles. The scale to be 2 inches to a mile, and the contours 75 feet apart. Time occupied 7 hours.

Sections 3–15.

(39.) Represent with shading a strip of a hillside, showing the slopes at which the movements of each arm become impracticable or very difficult, and also the limits for manœuvring ground for all arms. Indicate on it in figures the value of the slopes shown.

The slopes are to be properly blended, the one into the other, and the strip of ground represented is to occupy on the paper about three inches long by one inch wide.

Sections 105, 106.

(40.) Give an imaginary example of a sketch for a River-reconnaissance, and state the chief points to be noted in drawing up the report to accompany the sketch. Scale 2 inches to a mile. Represent about 3 miles of the river.

Section 22.

(41.) Construct a section from measurements given by yourself, and stated in a tabular form, and then lay down a plan of its contours. Show what calculations were necessary.

Sections 23–26.

(42.) Describe how you have been instructed to draw uncontoured models, giving an illustration of the different steps in the process.

Sections 38, 42.

(43.) What is triangulation? of what use is it? and what do you try to obtain in the selection of points for forming a triangulation?

Sections 4, 7, 83.

(44.) Supposing that you had been surveying for some time in one direction, what would you do in order to see if any error had unconsciously crept into the work, and how would the steps employed effect this object?

Section 51.

(45.) How would you find the breadth of a river which was not fordable?

Sections 101–103.

(46.) What are the points specially to be noted in making a reconnaissance of a road? Illustrate by a diagram the form which should be given to a road sketch and the tabular statement to accompany it. A few entries only need be made.

Sections 85, 86.

(47.) In surveying without instruments, what is the object of adjusting the ruler on the back-station? and how does interpolation in this mode of sketching differ from interpolation in surveying with the compass?

Sections 50, 18.

(48.) A tower AB stands on a slope inclined at an angle of 15° with the horizon. At a point C on the slope I find the angle of

elevation of the top of the tower to be 28° 30′, and at a point D 200 feet from C; in a direct line on the slope towards the tower I find the angle of elevation of the top to be 56° 15′. Find, by construction, the height of the tower, assuming the eye of the observer to be 5 feet above the ground. Assuming also the point C to be on the datum level, ascertain the height of the top of the tower above it. Scale 24 inches to a mile.

Sections 78, 54–59, 79.

(49.) Describe how the crest-line and afterwards the contouring is established on a Field-Sketch; stating which orthogonals are taken in preference, and how it is necessary to act when the conformation of the ground gives fractions of contours.

Section 82.

(50.) Given a "bench-mark" of 435 feet on one of the Forts on Portsdown Hill, near Portsmouth; what is the first thing to be done in making a contoured sketch of the ground, so as to make the contours correspond with the true levels above the sea?

Sections 37, 34.

(51.) Plot the following traverse made with a prismatic compass and pacing. Scale 8 inches to a mile.

	Bearings.	Distances.
From A to B,	5° 30′	180 yards
B „ C,	50° 15′	200 „
C „ D,	340° 0′	225 „
D „ E,	15° 30′	238 „
E „ F,	90° 0′	150 „
F „ G,	320° 15′	600 „

Ascertain and write down the distance from A to G, and the angle which the line joining A and G makes with the magnetic meridian.

Section 43.

(52.) On what principle are station-lines selected in traversing,

with reference to their lengths, number, and positions; and how are the angles affected by the selection?

Sections 37, 49.

(53.) Two towers, AB and CD, are observed to bear 45° and 22° 30′ east of north; and their angles of elevation are 22° 15′ and 18° 30′ respectively. After proceeding 450 yards west, their bearings are altered to 67° 30′ and 45° east of north; find the distances of the towers from each other and from the first place of observation. Find also their heights.

Section 34.

(54.) Supposing that some years after a survey had been taken, it was required to extend it on the same piece of paper; what is first necessary in order to have the means of protracting the angles to suit the fresh conditions of magnetic variation? Illustrate the answer by a hand sketch.

Section 7

(55.) Draw a scale of paces comparative to one measuring 3.5 inches to a mile, assuming the pace to be equal to 32½ inches.

Sections 37, 52.

(56.) A circular reservoir subtends at a certain point an angle of 34° 30′, and advancing 150 yards directly towards its centre, I find it subtends an angle of 72° 15′. Find its diameter by construction.

Section 79.

(57.) The crest-line of a hill having been finished, lay down to scale the following observations, made by compass, clinometer, and pacing, as near as possible along the orthogonal water-shed from one of the salients of the crest to a knoll below it, and show the shape of a small piece of each resulting contour.

A to B .	. 65° .	. 80 yards
B „ C .	. 40° .	. 120 „
C „ D .	. 350° .	. 50 „

Fall of one contour . .	15° slope
" " . .	10° "
" " . .	8° "
" " .	5° "

Level across the neck for 50 yards.

Rise of half contour . .	4° slope
" ,	7° "

Rise of one contour to top of knoll 10° slope

Scale 12 inches to 1 mile.

Contours 12½ feet apart.

Section 52.

(58.) A gentleman's house stands on the edge of a lake with a boathouse on the other side. From a point on the lawn they can both be measured, and are found respectively to be 120 yards and 372 yards from it, the angle formed between the lines being 75°. What is the distance across the lake?

Section 81.

(59.) What are the three different methods, irrespective of triangulation, of finding a place on the paper in field-sketching; and when would each plan be adopted?

Section 20.

(60.) In making a section of ground on a scale of ten inches to a mile, how can the necessary spaces between the parallels above the datum-line be found from the protractor, without actually making a scale?

Section 7.

(61.) A military sketch has no scale attached to it. The surveyor paces the distance between two houses shown upon it as five inches, and finds it to be 2153 paces. His pace equals 33 inches. Draw a scale of yards for the plan.

Section 47.

(62.) The length of Cleopatra's Needle is reported to be 68 feet 6 inches. If a staff six feet in length held up vertically beside it,

on level ground, casts a shadow of 3.75 feet, what would be the length of the shadow of the obelisk when the latter stood upright?

Section 31.

(63.) Show the entries properly arranged in a field-book of the traversing of a mile of road, working into it the following conditions:—

Five stations.
Eight houses (of which three are off the road).
One pond.
Six fields.

Section 82.

(64.) What is the object of marking "form-lines" in sketching ground? and when can thev be dispensed with?

Sections 1, 2, 96.

(65.) What is the use of making military surveys of portions of country, and how does military drawing tend to give a better appreciation of the ground?

Section 85.

(66.) How is the position of any object laid down on paper in eye-sketching, without the assistance of any other appliance than a ruler or scale?

Sections 76–80.

(67.) Give in detail the different stages to be prosecuted in the method of conducting a field-sketch, and state more particularly what "printing," "notes," or other information must be placed on it when finished, so as to make it as useful as possible.

Sections 102, 106.

(68.) State the two cases in which it may be necessary to make calculations as to "water," and what formula would be employed in each case.

Sections 81–84.

(69.) Draw from memory the contours of a part of the ground of one of your field-sketches, including the highest and lowest points, a knoll, and a spur. Number the contours from the lowest ground.

Sections 17–22.

(70.) Lay down a section from right to left, with the following measurements, on a scale of 8 inches to a mile, giving the heights exaggerated to the distances in the proportion of 6 to 1. Assume the point A at 140 feet above the sea.

Contours of 20 feet.		Horizontal Distances in yards.
From A to B	Level on plateau . .	300
B „ C	Fall	85
C „ D	Fall	110
D „ E	Level	70
E „ F	Rise . . .	65
F „ G	Level top of knoll .	120
G „ H	Fall	90
H „ I	Fall	140
	Total	980

Sections 54–59, 79.

(71.) Describe the process of tracing contours, and what steps have to be taken when the slopes change before arriving at complete contours.

Section 53.

(72.) A ship sailing south-west across the mouth of a bay rounds a promontory in view of a town, the court-house of which it wishes to shell from a point D. From a chart the following distances are obtained:—

From the promontory A across the bay to C = 1000 yards.
From the promontory to the head of the bay at B = 400 „
From C to B . . . . . = 700 „
The observed angles ADB = 35°, and BDC = 42°.

The court-house being in a continuation of the lines CB and DA, what is its range from the ship?

Section 31.

(73.) Give the reason for the conventional methods of making the following entries in a field-book :—

The parallel lines down the centre of the page.
The entries being made in succession above each other.
The lines across the centre column.
The side entries in the outer columns.
The small circles in the centre column.

Section 29.

(74.) Show infantry and cavalry in line and column, and guns limbered up and in action.

Section 79.

(75.) On pacing from the crest of a hill down a water-shed line, it is noted that the slopes change at 48, 10, 8, 18, 11, 15, 40, 60, and at 120 yards; mark in properly the contours and form-lines cutting the water-shed, number them, and enter the degrees of slope. Scale 12 inches to one mile, and no gradient exceeding 20.°

Section 13.

(76.) What do you understand by impossible contours? Give two or three examples.

Section 45.

(77.) Define the following terms :—

Bearing,	Interpolation,
Forward-angle,	Contour,
Meridian,	Plotting,
Traversing,	Off-set.

Section 42.

(78.) Plot a triangulation on a scale of 12 inches to a mile under the following conditions :—The point A being taken 750 yards from the north edge, and 670 yards from the east edge of the paper.

Base A to B = 164° and 550 yards.
A „ G = 18°
A „ C = 102°
A „ D = 175°

A to E = 186°
A „ F = 337°
B „ C = 39°
B „ D = 195°
B „ E = 217°
C „ G = 328°
E „ F = 354°
E „ H = 320°
F „ H = 233°

State which are considered good, indifferent, and bad triangles respectively; also give the bearing and distance of the check CH.

Sections 54–59, 79, 15–16.

(79.) Draw four lines, AB, AC, AD, and AE from the point A, forming three angles of 30° each.

Divide AB into 3 distances = 75, 80, and 155 yards.
„ AC „ „ = 200 yards each.
„ AD „ „ = 200, 250, and 50 yards.
„ AE „ „ = 175, 150, and 25 yards.

Assume that the points of division thus obtained mark points or stations on contour lines at 10 feet vertical intervals, the fall of the ground being in all cases in the same direction, and A being the highest point. Contour the ground, and fill in a portion with hachures in pencil. Scale, 12 inches to a mile.

Section 120.

(80.) Give a sketch of the positions of the reflecting glasses of a Watkin's Range-Finder when the index of the instrument is at zero.

Section 119.

(81.) Stump the sketch (a contoured one) to the depth of shade in which you have been instructed.

Section 7.

(82.) Construct a scale of Turkish Berris to use with a 6-inch sketch. The Berri = 1823.08 yards.

Section 36.

(83.) Give a diagram of a section passing vertically downwards from a line between the eye-hole and the vertical hair in the sight-vane of a prismatic compass, and explain how the simplicity of taking angles is arrived at.

Section 81.

(84.) Supposing that you were called upon to make a sketch of any proposed ground, what would be your first steps with regard to making yourself acquainted with the most desirable method of working it?

Section 102.

(85.) Explain the method of calculating for the supply of drinking-water for troops, whilst making a reconnaissance.

Sections 4–6, 30, 17–21, 27, 28.

(86.) Given a military drawing, about 8 inches square, from the Ordnance Survey of Kirkcudbrightshire, with the positions for three vertical intersection lines marked upon it.

Note :—The figures represent the heights in feet above the level of the sea. Scale, 4 inches to 1 mile.

Instructions :—Draw with pen, pencil, or brush, one quarter, or as much of this plan as time will allow, commencing at the top. The title is to be printed in the character used in the copy. Draw sections of the ground represented in the plan on the three lines AB, CD, EF : for the longitudinal distances the scale of the plan is to be used ; for the vertical distances, or altitudes, a scale three times that of the plan. Represent on any convenient scale a small portion of flat country, containing a wood, a marsh, and a village.

Sections 4–6, 17–21, 27, 28, 7.

(87.) Given a shaded piece of military drawing ($4\frac{1}{2}$ inches by $5\frac{1}{4}$ inches) from the Ordnance Survey of Northumberland, with the positions of two vertical intersection lines marked upon it.

Note :—The figures represent the heights in feet above the mean level of the sea. Scale, 6 inches to 1 mile.

Instructions :—Copy one-half of the sketch, either with the pen or pencil, or in brush-work. Draw sections on the lines AB, CD. Represent a marsh, a village, a sea-beach and overhanging cliffs, and a wood suitable for the above scale. Draw a scale for the plan.

126.—Summary of Answers.

There would be no object in giving in detail the answers to all the questions which have been selected for the previous Section, some being specimens of field-sketches, some examples of drawing, whilst others would be mere recapitulation of the text to be found in the body of the work; but it has been brought to the notice of the author, that in some cases the time both of the instructor and student might be materially economised by giving the general result of some of the answers.

With this view those questions which principally relate to plotting or construction have been here solved. When the number of any question is entirely omitted, no answer has been given.

(3.) Draw a line in any direction, although, to prevent confusion, it had better be drawn from the centre of the paper towards the right top corner. Protract an angle of 35° to the left of it, which will give magnetic north; then 18° 20′ laid down to the right of the latter will give true north in 1882.

(4.) Distance from C to D = 1990 yards.

(5.) Parallels 25 yards apart on the 6-inch scale.

(8.) The reduced level is 15.83, which will be found to agree with the difference between the sum of the back and fore readings, as also the difference of the rises and falls. Extreme distance of 710 links.

(10.) Representative fraction $\frac{1}{10560}$.

(11.) Magnetic and true norths to be found as in Answer 3. Angles plotted from the readings on the horizontal plate.

(12.) 32° = 90 yards, 17° = 170 yards, 4° = 720 yards, 25° = 115 yards.

(16.) Distance 25.70. Reduced level a fall of 9.77. See also answer to Question 8.

(17.) Solution, where the unknown point lies below the given triangle, BD = 540 yards. When above that triangle, BD = 405 yards.

(20.) This question might perhaps be better understood if it was put in the form :—"To find the prolongation of the capital of a bastion for the purpose of breaking ground from the second parallel."

Assume as an example, that on looking over the trench the prolongation of the two faces of the work are found to bear by compass 32° and 316° respectively. Subtracting 316° from 360°, and adding the difference of 44° to 32°, will give 76° as the whole angle formed by the contiguous faces with its bisection of 38°.

The surveyor must now move to the right along the parallel, till he discovers a point from which the salient of the bastion bears 38° less 32°, or 6° on the other side of north = 354°. If he chooses to move to the left from the point of his second observation, he must add 38° to 316° = 354°, giving exactly the same result.

(23.) Difference of level 136 feet.

(31.) Initial line = 5.68 inches.

(48.) Height of tower 72.5 feet. Height of top above datum level 139.75 feet.

(51.) Distance AG = 1205 yards, bearing 356½°.

(53.) Distance between towers 452 yards. First tower, distance 454 yards, height 570 feet. Second tower, distance 838 yards, height 867 feet.

(55.) There being nearly 1950 paces of 32½ inches in a mile; it can be found by proportion that a convenient number of 5000 paces will be expressed by 9 inches as the initial line.

(56.) Diameter of reservoir 510 feet.

(58.) Breadth of lake 360 yards.

(61.) 2153 paces of 33 inches give 71,049 inches between the houses. By proportion it will be found that a mile will be shown by 4.459 inches on the map.

(62.) Shadow of Cleopatra's Needle = 42.8125 feet.

(68.) Care must be observed that the velocity of the water is in one case noted in feet and in the other in yards.

(72.) Range of ship from court-house = 670 yards.

(78.) Check-bearing 277°. Distance 1425 yards.

(82.) The English mile being represented by 6 inches, the Turkish Berri of 1823.08 yards will be shown by a line of 6.215 inches.

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